THE EFFECTS OF FEED AREA DESIGN ON THE SOCIAL BEHAVIOUR OF DAIRY CATTLE

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Abstract

The overall objective of this thesis was to assess the effect of feed area design including feeding space availability, barrier type and stocking density, on the feeding behaviour of dairy cows. Feed intake in dairy cows is directly related to milk production, thus a good food supply is extremely important to the modern, high producing dairy cow. Intake is critical for improving milk production, health, body condition and the welfare of the animals. Feeding designs can have a major effect on behaviour and feed intake, therefore it is an important consideration when housing cattle and other livestock.

The effect of altering the amount of space allowance available at the feed-face highlighted a significant effect on feeding patterns. As the space allowance increased the number of feeding bouts also increased ($P<0.001$) and length of bouts decreased ($P<0.05$). However, when provided with extra space at the feed-face, cows did not increase their feed intake as hypothesised, possibly as a result of the differences between individual animals being masked by an overall group effect. The number of aggressive interactions decreased as the space allowance increased ($P<0.001$) and furthermore, the number of times individuals were displaced from the feeding area also decreased as the space allowance increased ($P<0.05$).

Subsequently, preference tests were used as a behavioural tool to determine how individual cows perceive their feeding environment with specific emphasis on understanding what difficulties low ranking animals face at the feed-face. Subordinate cows showed a significant preference for feeding alone rather than next to a dominant when they were offered high quality feed on both sides of a Y-maze test ($P<0.001$). When “asked” to trade-off between feed quality and proximity to a dominant cow, subordinate cows chose to feed alone on low quality food. A follow-on experiment using the same methodology was undertaken and aimed to identify the space allowances at which cows would not trade-off food quality. Four different space allowances were tested. At the two smaller space allowances, cows preferred to feed alone and for the two larger space allowances, cows had no significant preferences. The feed barrier has been shown to have a major effect on feeding and social behaviour of group housed dairy cows. A barrier design that provides some sort of separation between cows has also been shown to reduce competition. The aim of the final study was to determine if a feed barrier which obscured the cows' visual field whilst feeding would increase vigilance behaviour and alter normal feeding behaviour, particularly for subordinates. Two different types of feed barrier were tested at four different stocking densities. The average daily feeding time was higher when cows were fed using a conventional headlock system compared to an electronic feeding system ($P<0.05$). All groups of cows displayed vigilance scans, however, neither type of barrier, feed space allowance, or dominance rank had an effect on the frequency of scans. These results indicate that neither feeder design nor stocking rate affect vigilance in dairy cows, at least over the treatment conditions assessed in the current study.

The results of this research illustrate that to achieve the maximum levels of feeding behaviour and a reduction of aggressive behaviour, the cows' environment must be such that it provides sufficient space and feed barrier design which will allow normal social behaviour. Over-stocking at the feed-face should be avoided to reduce competition. Future research should consider the long term effects of over stocking and competition on dry matter intake (DMI), milk production and health.

Declaration

I declare that this thesis is my own composition and that the research described in it is my own work, unless stated otherwise.

Fiona C. Rioja-Lang

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Publications

Refereed Publications

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LIST OF ABBREVIATIONS

24h	24 hours
BCS	Body condition score
CH_4	Methane
CP	Crude protein
d	days
DEFRA	Department for Environment, Food and Rural Affairs
DIM	Days in milk
DM	Dry matter
DMI	Dry matter intake
DV	Dominance value
FAO	The Food and Agriculture Organisation
h	hour
HQF	High quality food
Kg	Kilograms
LQF	Low quality food
m	metres
ME	Metabolisable energy
min	minutes
N_2O	Nitrous oxide
NDFAS	National Dairy Farm Assured Scheme
NEB	Negative energy balance
n.s.	Non significant
s	seconds
SD	Standard deviation
TMR	Total mixed ration

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Rational For Research

Dairy farming is a significant farming activity for Scotland. Profit margins in milk production are currently very small, and there is increased pressure on farmers to comply with improved welfare standards. Insuring adequate nutrition significantly contributes to milk production. The modern dairy cow needs to consume a great deal of feed in order to support milk production. The composition of the diet is of obvious importance, but the way in which feed is presented when the cow is housed will also have an effect on the amount the cow is able to eat in one day. There is a large variation in milk yield within animals of the same genetic merit. While a certain level of natural variation is to be expected, the effect of competition for feed resources may be contributing. Aggression at the feed-face is at high levels in many farms, increasing frustration and stress, and causing injuries associated with falls.

Despite this, the design of feeders and feed-barriers for dairy cattle has been largely based on the physical size of the cow and the need to maximise the number of animals in any given feeding space, rather than on a consideration of the cow's preferred feeding behaviour and the effect of social interactions. Poor design may lead to lower feed intake and higher levels of aggression, especially in subordinate animals, with consequent detrimental effects on animal welfare, fertility and production. Therefore, this research consists of investigating the effect of factors such as space allowance, feed-barrier design and access to the feed-face on feed intake, aggression and feeding behaviour and milk production. As such, the work involves using a strategic scientific approach to investigating an issue relevant to Scotland's dairy farmers. Improving feeder design will improve animal welfare, and may also improved profitability.

Dairy cows must consume a large amount of feed to support milk production. In animals fed a prepared diet, the composition and palatability are very important factors, but the design of the feeding area is also very important in allowing the cow to fulfil her requirements. Failure to consume sufficient feed will result in reduced body energy reserves, affecting milk production and fertility. Additionally, a great deal of aggression occurs between animals at the feed-barrier. Aggression may result in injury to the recipient and stress in both aggressor and recipient. It has been shown that there are often high levels of aggression at the feed-face on commercial dairy farms (Haskell et al., 2003). Many cows, particularly younger animals, fail to achieve the level of milk production indicated by their genetic merit. This may be due to many factors, but the feeding regime may contribute. Research into feed intake has shown that daily feed intake is very constant, and when faced with competition for time or space to feed, cows vary feeding rates and length of feeding bouts to achieve this daily intake. However, the effect on milk yield, and the stress experienced by cows who are forced to modify their preferred feeding patterns has not been considered. If feed-barriers were designed to take account of the social and feeding behaviour of the cows, feed-intake and welfare could be optimised.

CHAPTER 1

General Introduction

1.1 Concern for animal welfare

Since the 1960s, livestock production has experienced unrecognisable changes. The increase in production has been accompanied by many changes in production practices. For example, many extensive production systems gave way to more industrialised “confinement” systems especially for those species that are fed on concentrate diets (Fraser, 2008). The reasons for these increasingly intensified production practices are based on improving economic efficiency. These changes can be seen mostly in the production of poultry, eggs and pigs, however there has been much less change in production methods for sheep and goats which continue to be raised extensively. These changes in housing, combined with changes in nutrition, health care and genetics, as well as the widespread adoption of new technologies, have also led to significant changes in product yield (Mench, 2008).

Numerous practices of intensification, such as the use of farrowing crates for sows, caging laying hens, high stocking densities, and the prolific use of antibiotics have been fiercely criticised. For example, it has been known for some time that farrowing (parturition) crates reduce sow welfare by thwarting nest building behaviour, which may be observed as a redirected behaviour towards other substrates (e.g. floors and bars). Restriction on the performance of this highly motivated nest building behaviour may be perceived as aversive by the pig (Jarvis et al, 2001). Previous work has shown that gilts housed in crates without straw and expressing such re-directed nest-building behaviour have increased concentrations of plasma ACTH (Jarvis et al., 1997) and cortisol (Lawrence et al., 1994; Jarvis et al., 1997). Dairy farming is a semi-intensive agricultural sector, and there are also a variety of concerns regarding the welfare of dairy cattle (particularly of those housed permanently indoors). These changes in intensification of agricultural systems may be the reason for the large growing concern regarding animal welfare by the general public, particularly throughout Western Europe, although it is increasingly becoming a global concern. Another possible explanation for this is a growing acceptance that animals are sentient (i.e. they have the capacity to ‘feel’ in a way that is analogous to human experiences’) (Lawrence, 2008). However, it was the publication in 1964 of Ruth

Harrison's book Animal Machines, in which she described many of the conditions under which modern farm animals lived. It was this book, plus the subsequent setting up by the British Government of the Brambell Commission ‘‘to enquire into the welfare of animals’’, which were among the main incidents responsible for the initiation of farm animal welfare legislation in the United Kingdom (Rushen, 2008).

The problem in objectively assessing welfare from any standpoint is the inherent inadequacy of the abstract concept of welfare (Hemsworth et al., 1995). One of the most commonly cited definitions of welfare is "an animal's state as regards it attempts to cope with its environment" (Broom, 1986). One of the most simple definitions of welfare can be described as being a reflection of people's concern with the well-being of animals (Albright, 1987). The debate surrounding the definition of welfare and the uncertainty of terminology does not remove it from the real experience of the animal. An assessment of an animal's welfare would ideally incorporate both physiological responses and how they are 'feeling' at that time. However, feelings are difficult to measure therefore it is more likely to concentrate on more easily quantified parameters, such as strength of their preference for different environments (Phillips, 2002). The potential value of welfare indicators lies in the identification of welfare problems associated with particular aspects of systems and their management (Fregonesi and Leaver, 2001). Some indicators are believed to be better than others, e.g. milk production as an indicator may have limitations, as it is influenced by genetic factors and a range of environmental factors including nutrition, disease, milking management and climate. With regard to the welfare of dairy cows, it is already well documented that aspects of housing design have a significant impact on welfare (Potter and Broom, 1990). Likewise, the management system under which cattle are kept has the potential to place stress on the animals and therefore be detrimental to animal welfare (Logue, 1996). To assess the effect that the housing design and management system has on the welfare of the cows, the consequences for the animals must be measurable, and therefore health, behaviour and physical condition must all be considered.

It is arguable that the single most significant event in the application of science to animal welfare happened in the period between 1970 and 1980, when applied animal behaviour scientists began developing scientific approaches to assess the ‘animal’s perspective’ (Lawrence, 2008). For example, since the early 1970´s, scientists have used preference tests (tests that require animals to choose between two or more different options) to establish animal’s preferences for common housing conditions (Fraser and Matthews, 1997). Researchers also developed techniques to measure the strength of motivation based upon consumer demand theory (Lea, 1978; Dawkins, 1983a; Sherwin, 1996; Mason et al., 1998). This approach requires animals to pay a cost, usually in an operant task, to gain access to a resource or to perform a behaviour. Both of these techniques have been used in a wide range of species including laboratory mice (Sherwin, 1996), laboratory rabbits (Seaman et al., 2008), mink (Cooper and Mason, 2000), chickens (Dawkins, 1977) and cattle (Pajor et al., 2003). Another approach, sometimes referred to as the ‘best estimate’ approach requires measurements of parameters that are arguably indicators of welfare, these include stress physiology, behaviour, mortality, health and productivity (Hemsworth et al., 1995).

The aim of this thesis is to utilise some of these scientific methods to investigate the feeding behaviour of dairy cows, paying particular attention to investigating the effect of dominance and competition on the welfare of subordinate individuals. Many researchers have studied the physiological and nutritional aspects of feeding by dairy cows (e.g. Chase, 1988; Butler, 1998; Chagas et al, 2006). This is obviously an important consideration, particularly for the lactating dairy cow that has to meet high energy demands. However, an area which has often been overlooked is the physical and social factors such as housing and dominance structures within the herd. Therefore, this chapter aims to review the body of literature surrounding feeding behaviour of dairy cows and the behavioural tools that are available to measure it. The aim is also to identify the areas requiring further research.

1.1.1 Modern Dairy Farming – the UK perspective

Dairy farming in the UK is a semi-intensive livestock industry which accounts for around 18% of UK agricultural production by value. In 2007, there were around 17,915 dairy producers in the UK (Dairy Co, 2008). The average herd size in the UK is 112 cows per herd (with considerable regional variation). This is significantly above the EU average of 45 cows, and the trend is for the herd size to increase further. Rapid increases in milk production have been brought about by a combination of genetic selection, and improved feeding, health and management. The current average yield in the UK is around 7,000 litres per cow per annum (Dairy Co, 2008). This figure is almost seven times the required volume of milk of a cow suckling a calf (Table 1.1). This massive increase in milk yield has led to dairy cows having considerably increased nutrient requirements in order to maintain this level of production.

A typical lactation curve of a dairy cow shows a peak or maximum daily yield occurring 4-8 weeks after calving, followed by a daily decrease in milk yield until the cow is dried-off, or production is naturally completed. Cows utilise feed more efficiently in early lactation, partly due to catabolism of body fat accrued prior to calving (Ferris et al., 1985). Intake potential has not kept up with the potential increase in milk production, therefore an increasing proportion of energy needs come from the mobilisation of energy reserves (Veerkamp et al., 2003). Negative energy balance (NEB) can lead to substantial body condition loss, subclinical ketosis, greater susceptibility to disease, and production decline due to poor reproductive performance later in lactation (Heuer et al., 2000).

Table 1.1 Comparison of milk production in feral and modern domesticated dairy cows (Phillips, 2002).

	Feral	**Domesticated**
Milk production (L/day)	8 – 10	30 – 50
No of milkings per day	4 – 6	2 – 3
Yield per milking (L)	1 – 2.5	10-25
Total lactation yield (L)	<1000	6000 - 12000

One of the primary objectives of dairy producers is to promote dry matter intake (DMI) to support this high level of milk production (Huzzey et al., 2006). Feed intake in dairy cows is extremely important to the modern, high producing dairy cow; and insufficient quality or quantity is an obvious welfare concern (Grant and Albright, 1995). To achieve the greatest intensity of feeding behaviour, the cow's environment must be such that it ensures cow comfort, non-disrupted feeding activity and normal social behaviour. Dairy cattle have the ability to consume feed extremely efficiently; however this may be affected by several factors, such as group size, feeding system design and apparatus, and attributes of the feed itself. Lactating dairy cows will spend 3-5 hours per day eating when given continuous access to a total mixed ration (TMR) (Grant and Albright, 2000). Despite the importance of this activity, very little research has been undertaken on how to design a comfortable environment for feeding (von Keyserlingk and DeVries, 2004).

The systems in which dairy cows are kept are diverse, ranging from highly mechanised systems in which the cattle are kept indoors all year, to extensive systems in which the cattle are outdoors permanently (Phillips, 2002). Individual farms vary in many aspects of management and husbandry, including building design, feeding regime, and grouping structure. In the UK and North America, systems in which cows are housed continuously throughout the year, are becoming more common. This is primarily because cows can be fed high levels of concentrate feed more easily which is useful for cows with a high genetic potential for milk yield

(Haskell et al., 2006). Group feeding of cattle results in competition between animals, particularly under restricted feeding conditions and with limited access to feeding equipment (Oloffson, 1994). Maintaining dairy cows of different ages, sizes and production status in the same group, results in highly variable nutrient requirements among the cows. Such management systems may be stressful and suboptimal with regard to the utilisation of the production potential of cows (Oloffson, 1994). In these competitive environments, it is common for the lower ranking animals to miss out on access to resources, particular at preferred feeding times.

1.2 The importance of feed intake

In its simplest definition, food is the material which can be ingested by animals and is subsequently digested, absorbed and utilised. The consumption of food is a complex activity and consists of a series of behaviours involving the identification of a possible food substance, and sensory appraisal before ingestion. Feeding is the predominant behaviour of ruminants and this is illustrated by the fact that feeding activity has priority over rumination whenever the causal factors of the two activities conflict (Metz, 1975). The unique digestive system of ruminants allows them to efficiently utilise feed that humans are unable to utilise, and in turn produce products such as milk and meat, that humans are able to consume (Van Soest, 1994).

Dairy cattle nutrition can be defined broadly as the use of the components of feeds for the processes of maintenance, growth, reproduction, lactation and health (Drackley et al, 2006). The diet of farm animals in particular consists of plants and plant products, although some foods of animal origin such as fishmeal (not permitted in the UK) and milk are used in limited amounts (McDonald et al., 2002). Generally, the nutrient requirements of a lactating dairy cow will depend directly upon the volume and composition of the milk being produced. There is a great deal of evidence to show that reduction of feed intake has a profound effect upon both the yield and the composition of milk, with yields dropping to ~ 0.5kg within 3 days of being kept without food (McDonald et al., 2002). The increased genetic merit for milk yield of the modern dairy cow has resulted in an animal that can be susceptible to shortfalls in nutrient intake in order to maintain production. In this case, cows have to "shift" nutrients away from maintaining functional fitness (seen as reduced body condition score [BCS]) (Veerkamp et al, 2001; Dechow et al, 2002; and Wall et al, 2007).

1.2.1 Feeding Behaviour

Food preferences and social interactions are usually the main factors that influence diet and habitat selection in domestic grazing herbivores (Dumont and Boissy, 2000). Under range conditions, there are complex interactions between social grouping tendencies and foraging decisions. Early social experiences (Howery et al., 1998) and social cohesiveness affect the distribution patterns of cattle, together with fluctuating water and vegetation availability (Dumont and Boissy, 2000). Most species of large ruminants form social groups which is reflected in their distribution while grazing. In grazing sheep, for example, clustering can be observed due to the existence of sub-groups, which may be peer or family groups. However, the extent of clustering will vary among breed (Arnold et al., 1981). Within a breed, the distance between grazing individuals can be altered by the vegetation, decreasing as vegetation quality and homogeneity increase (Dwyer and Larence, 1997).

Curtis and Houpt (1983) reported that group-housed dairy cows indoors tend to synchronise their behaviour particularly at feeding. They reported that when cows are fed in groups, the act of one cow moving to the feed-face stimulates others to feed. When one cow eats, another might be stimulated to do likewise, whether she is hungry or not. Studies have also indicated that this synchronisation of behaviours may be reduced when cattle are housed intensively indoors (O'Connell et al., 1989; Miller and Wood-Gush, 1991), perhaps as a result of increased competition for resources. Reduced space and constant regrouping of cows causes increased aggression, partly because cows have to compete more for eating and lying places (Galindo and Broom, 2000).

Key components in determining feeding behaviour are the social hierarchy, competition for feed, water, space and feed availability within a group of cattle (Grant and Albright, 2000). Feed intake and consequent milk yield are improved by providing feed when cows need and want to eat. Traditionally, cattle have been thought to exhibit diurnal feeding patterns whereby they consume the majority of their daily dry matter intake (DMI) between dawn and dusk (Hafez and Boissou, 1975). More specifically this is referred to as crepuscular feeding, with their largest and most extensive meals occurring at sunrise and sunset (Ray and Roubicek, 1971; Hafez and Boissou, 1975; Ruckebusch and Bueno, 1978).

Many high genetic merit cows' capacity to produce milk largely exceeds that of the capacity to consume sufficient nutrients for milk synthesis. Table 1.2 estimates the food intake (dry matter) that high-genetic merit Holstein cows may reasonably be expected to achieve in three different circumstances: at pasture, when fed silage and concentrates twice a day, or then fed a balanced total mixed ration (TMR). The level of nutrient intake has been used to estimate an average level of milk production.

Table 1.2 Milk yields and dry matter intakes of Holstein/Fresian cows in different circumstances (Webster, 2005).

	DM Intake (kg/day)	**Sustained Yield (l/day)**
Pasture	16	25
Grass silage + concentrates (x2/day)	20	36
Total mixed ration	26	55

When dairy cows are feeding at pasture, their intake is restricted by time, and their physical ability to graze. However, cows fed grass silage and concentrates during milking are able to support higher levels of milk production. The highest levels of feed intake, and subsequently milk production are of those cows fed on an *ad libitum* TMR. The aim of the TMR is to promote rapid, stable fermentation, and so to reduce the constraints presented by both rumen fill and high blood urea concentrations. It is these carefully balanced diets that have provided the modern, high yielding cow with a vehicle in which to express their physiological potential of large milk production rates. However, this potential also provides the cow with conflicting physiological motivations. She is motivated to eat by metabolic hunger (a function of both milk yield and body condition); however, she is motivated to stop eating by sensations associated with gut fill, unbalanced absorption of certain end products of rumen digestion (especially ammonia), and the conflicting desire to perform another behaviour, such as rest.

1.2.2 Stocking Densities

Stocking density is the term usually used to describe the space allocation for animals during confinement. Individual spacing patterns can cause considerable problems when animals are reared commercially in either intensive or extensive conditions and during transportation. The aim of such rearing patterns is usually to get the maximum density and/or growth rates at a minimum cost to the producer. Livestock producers that raise animals in large groups and high spatial density do so to reduce labour and building costs. However, this style of management may influence behaviour and production performance of animals (Kondo et al., 1989). Space is incredibly important, as ultimately it determines which behaviours animals will be able to perform and for how long i.e. feeding, drinking, resting, grooming, social behaviour etc. When cattle are stocked in such high densities, it becomes very difficult for animals to avoid violation of individual distance zones; consequently there is an increase in levels of agonistic interaction. For example, in a situation of high stocking density the social behaviour of dairy cattle will mean that dominant animals may exclude subordinates from feeding areas, and in some cases the mere sight of a dominant can suppress feeding, and even maturation and reproduction, in subordinates (Phillips, 2002).

1.2.3 Measuring Feeding Behaviour and Feed Intake

In the sections above, I have discussed how group feeding, cow density, and distribution of feed all interact and cause cows to behave a certain way whilst feeding. Now, I will go on to describe feeding behaviour of dairy cows in more detail and also how it can be measured. The use of time-lapse video recording and recent advances in the development of computerised recording systems have resulted in a refreshed interest in obtaining information on feeding behaviour (Gibb et al., 1998). I will go on to discuss the existing literature on this subject and other behavioural tools available to investigate feeding behaviour.

1.2.3.1 Feeding Bouts and Meal Criteria

Grant and Albright (2000) reviewed much of the literature regarding feeding behaviour and concluded that management factors, feeding systems and other non-nutritional factors can all affect the feeding behaviour of cattle. However, DeVries et al (2003a) highlighted the need for research on more basic issues such as the temporal patterning of feeding, and how feeding bouts are divided into meals. They suggest that this basic work can provide a solid baseline for comparing measure of feeding behaviour across studies.

Studies of short term feeding behaviour are concerned with the feed intake patterns of animals at the level of feeding events and meals (Howie et al., 2009). A common definition of a meal is a cluster of feeding events separated by short intervals (Mayes & Duncan, 1986). It can be distinguished from the next meal by a non-feeding interval that is long compared to the intervals within the meal (Sibley et. al., 1990). Feeding behaviour consists of feeding events, separated by non-feeding intervals (Tolkamp et al., 1998; Tolkamp et al., 2000; Yeates et al., 2001). However, identifying which intervals are between meals, versus shorter gaps within a meal, can be problematic. For example, in some cases a cow may lift her head for only a few seconds, in others, she may withdraw from the passage for less than a minute or so when, for example, she is displaced by a dominant cow and must move to another location on the passage. If the meal is the unit of feeding behaviour that is of interest, then a meal criterion must be determined (Bigelow and Houpt, 1988). When visits to the feed-face are grouped into meals, the number of meals correlates negatively with the social dominance of the cow; namely, dominant cows have fewer meals (Oloffson, 1999). Feeding events can be the unit in which feeding behaviour is analysed (Nielsen et al., 1995). However, the definition of a feeding event is affected by the methodology used to collect data and the accuracy of the measurements (Tolkamp et al., 2000). This makes it problematic to compare studies of feeding behaviour that use different methodologies. Therefore, robust comparisons can only be made between results of studies with similar recording methods and resolution (Demaria-Pesce and Nicolaidis, 1998).

Much work has been done in this field by Tolkamp and colleagues (Howie et al., 2009; Tolkamp et al., 1998; Tolkamp et al., 2000). They identified the importance of the fact that the probability of an animal initiating the next meal is expected to increase with time since the last meal, and therefore, meals will not likely be randomly distributed. Whereas previous approaches had assumed that the probability of an animal initiating a meal was independent of time since last meal (Slater and Lester, 1982; Sibly et al., 1990; Langton et al., 2008). Tolkamp et al (1998) have described a $\log_{10}$-normal model which provides an objective basis for biologically relevant calculations of meal frequency, meal durations, and total daily mealtime. It is important for future research that authors can agree as to how feeding events are clustered into meals and can be repeatedly and accurately measured.

An initial step in improving the feeding environment is to understand the feeding patterns of loose housed cows and the impact that various management factors can have on these patterns. In a recent study by DeVries et al (2003a) they examined the normal feeding pattern of lactating cows housed in a cubicle housed environment given unrestricted access to the feed-face (Figure 1.1).

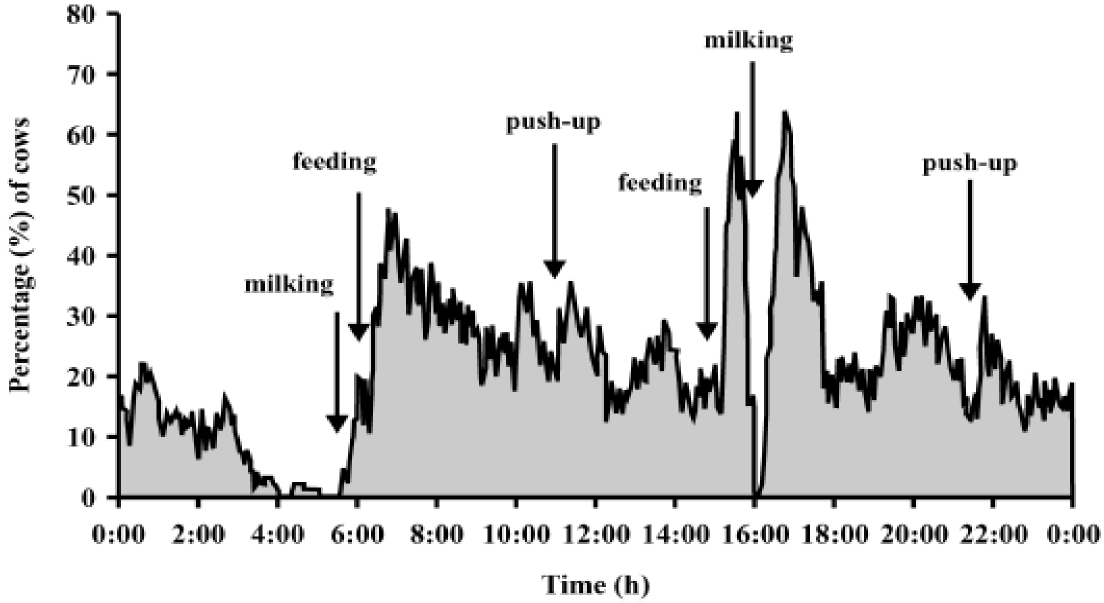


Figure 1.1 Percentage of 24 cows present at the feed alley over a 24h period (percentage for each 60s interval during the day) averaged over 4d while cows were on baseline feeding schedule (DeVries, 2003a).

In this study they found that cows consumed on average 7.3 meals per day and spent approximately 6 hours at the feed-face over a 24 hour period. Of particular interest was the 24 hour diurnal pattern of feed-face attendance (De Vries et al., 2003a). They also found that the management practices of milking and delivery of fresh feed had the greatest impact in terms of mobilising animals to come to the feed-face. Similar data on the duration of eating were previously reported by Metz (1975) who recorded an average number of meals being 8.3. Tolkamp et al (2000) also recorded meal characteristics of cows with access to 3 different feed types (high protein feed, low protein feed and high and low protein feed as a choice). The number of meals per day recorded in this study ranged from 5.8 to 6.7 meals. The number and length of feeding bouts will vary between individuals depending on age, stage of lactation and position within the dominance hierarchy, however from this small number of studies we can predict that the average number of meals will vary in the range of around 6-8 per day.

These short term feeding behaviours can be used to test hypotheses on the control of feed intake and diet selection, including the roles of hunger and satiety (Tolkamp et al., 2000; Gonzalez et al., 2008). These definitions of feeding characteristics are useful from a nutritional point of view, however, not necessarily from a behavioural point of view. When recording feeding patterns, Tolkamp et al (1998) and Tolkamp et al (2000) ignore any interruptions to feeding caused by aggression or displacements by other cows. Therefore, for this type of study, it may be more beneficial to use actual observed behaviour to describe feeding behaviour patterns. All of this information will be considered whilst designing experiments to understand how various aspects of the feeding environment (feed barrier type, space allowance etc) affect feeding behaviour.

1.3 Social Hierarchy

Social order, rank order, pecking order, dominance and hierarchy are all names that have been widely used for the phenomenon between a pair or group of animals where the behaviour of one may be inhibited by the other, and for the resultant complex of relationships found in groups of animals (Beilharz and Zeeb, 1982). In semi-wild or wild cattle, the social organisation of the herd takes the form of matriarchal groups consisting of mother and offspring, and separate bachelor groups of bulls. In domesticated cattle, however, these natural groupings are replaced by groups of cows and growing cattle, usually divided into similar age and single sex groups after about six months of age (Phillips, 1993)

Social dominance plays a pivotal role in any existing, or newly formed group of cattle. Studies have reported a weak correlation between social rank and milk yield, although social rank sometimes has been associated directly with body weight, age or breed (Shein and Forhman, 1955; Collis, 1976; Lamb, 1976). Although weight and size are correlated with age, the social skills necessary for gaining a high rank also need to be learned. This usually occurs as juveniles during play, and animals reared in social isolation are usually dominated by animals reared in groups (Broom and Leaver, 1978).

In all intensively managed stock the existence of a strict hierarchy reduces aggression by eliminating the need for repeated agonistic encounters to determine priority to resources. For example, spatial priority relates to access of lying areas, in particular cubicles. Cubicles in the centre of a line or those with enclosed fronts will be occupied by high ranking animals at preferred times (Phillips, 2002). Animals close in the dominance order need to confirm status more regularly, and changes in order may occur in 25% of the herd annually (Phillips, 2002). Older members of the herd with an established position initiate less aggression, because experience in the herd conveys social advantage. Younger members must constantly challenge older members to elevate their position in the hierarchy. Under conditions of excessively large group sizes, individual animals have difficulty memorising the social status of all peers, which increases the incidence of aggressive interactions (Hurnik, 1982).

In all ruminants, social hierarchies determine an unequal access to various resources. The social structure of domestic pigs is also based on a dominance hierarchy. However, this strict hierarchy is often established only after vigorous fighting when unfamiliar pigs are brought together (Meese and Ewbank, 1973). This aggression will quickly decrease, or more likely disappear once a mutual dominance relationship has become clear. Unfortunately, in commercial pig production, repeated regrouping is common practice resulting in the frequent formation of new hierarchies. It is well known that high rates of aggression are involved in this process, which in turn cause serious problems in animal welfare and performance (e.g. Stookey and Gonyou, 1994; Puppe et al., 1997; Gonyou, 2001). Likewise, chickens will also show aggression towards unfamiliar birds, and will eventually form a dominance hierarchy within the group (Rushen, 1982; Syme, 1983). Problems may arise when birds are kept in groups of several hundreds, or thousands, and are unable to form dominance relationships with all individuals. This kind of commercial situation may lead to birds constantly encountering strangers, therefore leading to social instability. Social rank may be less obvious in sheep than in other species (Lynch et al., 1992) however, it still affects sheep behaviour. For example, a dominant ram will sire more offspring that other rams (Fowler and Jenkins, 1976).

1.3.1 Dominance

The social hierarchy is particularly important in intensive husbandry, as there is little opportunity for low ranking individuals to escape. It has even been suggested that social dominance is the most important component of social behaviour (Syme and Syme, 1979). One definition of dominance is that it is an attribute of the pattern of repeated, agonistic interactions between two individuals, characterised by a consistent outcome in favour of the same dyad member and a default yielding response of its opponent rather than escalation. Schein and Fohrman (1955) were the first to systematically describe social dominance in cattle. They suggested that one animal in a pair could threaten the other without retaliation (unidirectional aggression) and that these dominance relationships were transitive (i.e. if $A > B$ and $B > C$ then $A > C$). Asymmetrical dominance or (intransitive dominance) relationships have also been described (i.e. where $A > B$ and $B > C$, but $C > A$) (Reinhardt and Reinhardt, 1975; Beilharz and Zeeb, 1982; Wierenga, 1990). In the presence of a dominant cow, subordinate cows take evasive action, and in a confined space such as cubicle housing, many escape attempts take place each day (Potter and Broom, 1990). For economic reasons, stocking densities on farms are normally greater in housing than at pasture. This dichotomy can lead to social tension in the cattle housing system, as the maintenance of personal space is one of the main status symbols for cattle (Phillips, 2002). However, as the dominance order becomes established in a herd, the aggression becomes ritualised, and this is more common in cattle than any other ungulates (Phillips, 2002). Little more than a swing of the head may be needed to confirm the status of the dominant animal and a slight avoidance movement by the subordinate animal.

1.3.1.1 Methods of dominance testing

Detailed observations of agonistic behaviour within groups of cattle have shown several limitations of the classical properties associated with the concept of the dominance hierarchy: indeed, bi-directional agonistic behaviour (where both animals of a pair initiate aggression) and intransitive dominance relationships are commonly noted (Reinhardt and Reinhardt, 1975). To date, there is no unified methodology as to how one should describe a dominance hierarchy of a group of animals. Val-Laillet et al (2008) recently described an experiment in which they recorded displacements at the feed-face of six groups of twelve cows and compared the advantages and disadvantages of three dominance indices commonly used for describing the competitive success at the feeder. The Galindo-Broom Index estimates how good an individual is at frequently displacing other cows within the group without being displaced frequently herself. The index proposed by Mendl et al (1992) evaluates how good an individual is at being able to displace others at least once without being displaced. The index developed by Kondo and Hurnik (1990) assess how good an individual is at being dominant in dyadic interactions.

Correlations between the three different indices were assessed using the *Fisher's* r to z test. The results suggested that there were moderate and high correlations between each index, but there was no correlation between any of the indices and total time spent at the feeder. Val-Laillet et al (2008) also suggests that the Galindo-Broom Index was the most discriminative, whilst the Kondo-Hurnik Index was the least discriminative. Despite numerous similarities and strong correlations between the three indices, there are subtle differences that can affect the tanking outcomes. The results of the trial did not observe any cow which was dominant over all others in her group, which is in agreement with Beilharz and Zeeb, (1982). The author concludes that there is some doubt over the value of classical properties of social dominance. Dairy cows establish a hierarchy in which the transitivity is lessened by many circular triads and many dominance relationships are bi-directional. This suggests that the classical properties of social dominance (asymmetry and transitivity) do not correspond to the pattern of displacements that occur at feeders within small groups of cattle (Val-Laillet et al., 2008). It is very likely that dominance observed at the feeder is also affected by such factors as motivation at that time and persistence to access the resource. Despite these obvious difficulties and limitations, when a linear hierarchy is difficult to calculate, an index (such as those shown above) can help to compare the competitiveness of individuals for resources.

1.3.2 Competition for Feed

Being able to calculate the dominance status of individuals within a group, as described above, helps in understanding how individuals are affected in competitive feed situations. Food competition is a basic ecological process, occurring when food resources become limited (Wilson, 1975). Most animals differ in their competitive abilities, yet many commercial rearing systems are based, at least initially, on the assumption that resources will be shared equally between all individuals (Monaghan and Wood-Gush, 1980). Domestic animals are thus often forced to feed in conditions where competition is intense. Social hierarchies and the competition for feed and water affect feeding behaviour. A highly competitive time at the feed-face or feed area is reported to coincide with the return of cows from milking and when fresh feed is offered (Friend and Polan, 1974). As fresh feed is highly valued by cows, and there may not always be sufficient space for all cows to feed at once.

Oloffson (1994) evaluated the effect of increasing competition per total mixed ration (TMR) feeding station from one cow to four cows/station. As competition per feeder increased, cows exhibited shorter average eating times and accelerated eating rates. Similarly, visits to the feeding station increased in direct proportion to greater aggression during feeding. In contrast, when cows were fed limited amounts of feed, dominant cows consumed 14% more feed than submissive cows.

Oloffson (1999) also noted in a study of time budgets that the cows altered their behaviour when the competition for the total mixed diet increased. A significant decrease in eating time was compensated by a significant increase in time spent standing, especially for cows with a low dominance value (DV). Under these conditions of limited feed availability, competition escalated and feed intake of submissive cows suffered.

1.3.3 Aggression

Aggression involves motivation and behaviours that result in repelling other animals (Beilharz and Zeeb, 1982). In aggression, the main forms of tactile interaction between cattle are charging, head pushing, butting and occasionally kicking. Feed area design plays an important role in facilitating aggressive feeding behaviour. In a study conducted by DeVries et al (2004) they tested whether increasing the space availability at the feed-face improved access to the feed and reduced social competition. Twenty-four lactating Holstein cows were each tested under two conditions: 0.5m or 1.0m of feeding space per cow. The results showed that when animals had access to more space they observed 57% fewer aggressive interactions while feeding. This reduced aggressive behaviour consequently allowed cows to increase feeding activity throughout the day. The increase in feeding activity was found to be especially noticeable during the first 90 minutes after fresh feed was provided (Figure 1.1). During this period, cows with access to more feeding space increased time at the feeder by 24%, and this effect was strongest for subordinate cows.

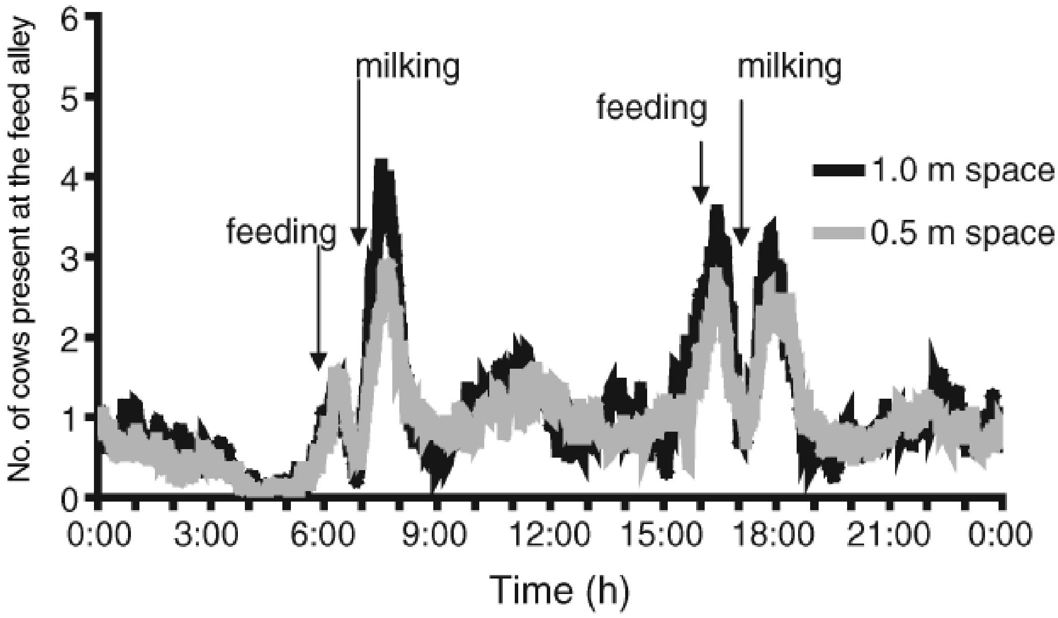


Figure 1.2 Feed–face attendance at two levels of feeding space (DeVries et al., 2004).

Previous research on feeding space had concluded that dairy cows can be kept with as little as 0.2m of feeding space per cow without adversely affecting DMI or milk production (e.g. Friend et al., 1977, and Collis, 1980). However, increased animal densities are linked to reduced inter-individual distances and increased aggressive behaviour (Kondo et al., 1989; Keeling and Duncan, 1989), which may impact on welfare.

1.4 Dairy Cattle Feeding Designs

It has been suggested that when dairy housing facilities are being designed, a limited feeding area might be profitable and recommendable if the increased competition for feed does not harm the welfare of the animals or affect production negatively (Oloffson, 1999). However, even when free access to forage in sufficient amounts is available, cattle interact in ways that might give some individuals advantages over others in the herd. A limited feeding area most likely favours cows that are high in social rank.

The design of standard animal feeding troughs or barriers can give rise to behavioural problems. These problems can be observed within most commercially produced species. For example, domestic pigs kept in groups soon form hierarchies and dominant individuals often monopolise resources. This resource defence is rarely visible in more natural conditions as pigs are usually feeding on dispersed feed several meters apart. Stolba (1985) carried out a series of behavioural experiments in which he varied the way in which food was presented to a group of pigs. By monitoring the behaviour of individuals he was able to determine the conditions which minimised differences in feeding rates between dominants and subordinates. He found that increasing the lengths of the troughs decreased their defend ability and allowed subordinates access to feed without being in close contact with dominants. Stolba (1985) then tried various ways of screening the feeding pigs from each other. He found that the most cost effective method, in terms of financial outlay and behavioural results, was to divide the trough into individual sections using small screens placed along its length (bin stalls) (Figure 1.2). The screens effectively prevented each pig at the trough from seeing the head of its neighbour, and reduced both the incidence and effect of threat posturing by dominants.

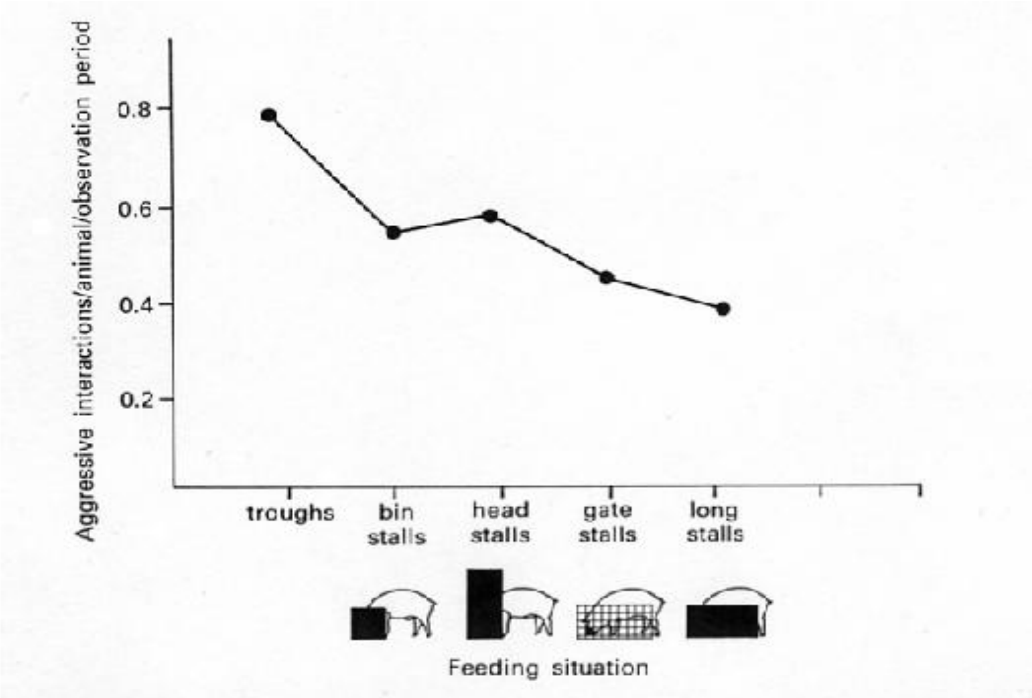


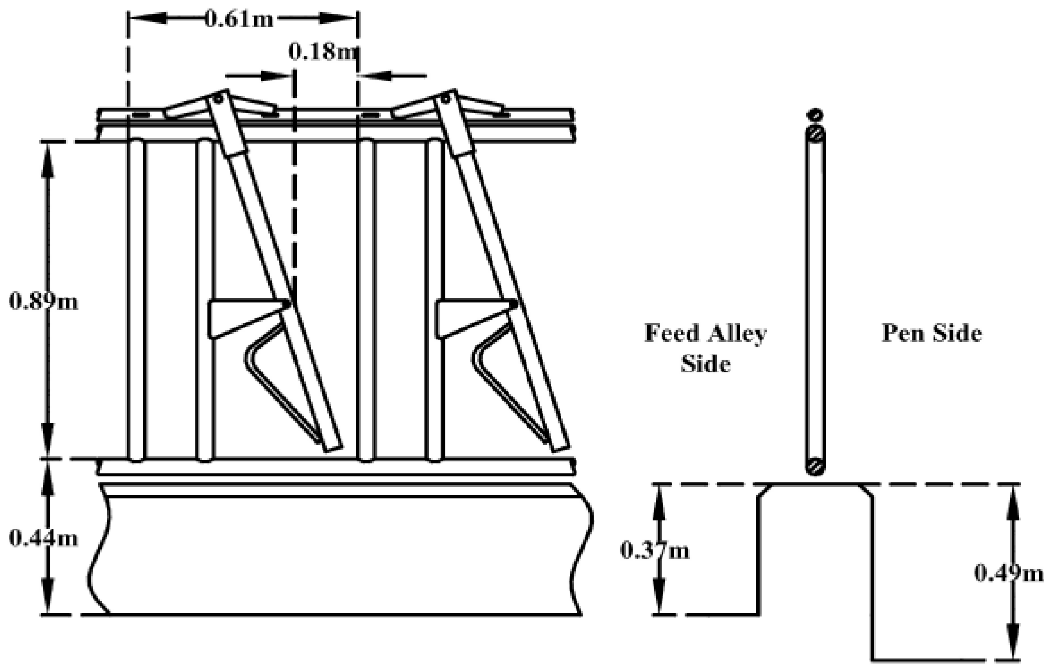
Figure 1.3 Frequency of aggressive interactions per pig during a 20 minute observation period of 10 pigs in different feeding situations (Stolba, 1985).

A well-designed management system should adequately accommodate normal feeding behaviour to improve animal comfort and well being. Likewise, animal grouping strategies can reduce competition for feed at the feed-face and improve feed intake. Feeding space or feed availability should not be limited to avoid reductions in feed intake for the more submissive animals. Reduced feeding space has been shown to result in increased agonistic behaviours in cattle (Kondo et al., 1989). For cattle, which often displace one another when feeding by swinging and butting with the head, modifications that restrict head and neck movements may be particularly effective in reducing competition and improving access to feed (Endres et al., 2005).

1.4.1 Feed Barriers

Fence line feeding, or strap feeding, is designed to allow all cows to feed at the same time (Figure 1.4). It is also the most common method used in free stall or cubicle house dairies. However, the characteristics of the physical barrier separating the cows from where the feed is delivered may also affect feeding behaviour (von Keyserlingk and DeVries, 2004). A barrier design that provides some sort of separation between cows (e.g. headlocks) may reduce competition by making it more difficult for cows to displace each other (Huzzey et al., 2006). Further research is required to substantiate this idea, as the research that has previously been done reported variable results. A recent study by Endres et al (2005) compared the effects of using a headlock and post-and-rail feed barrier on the feeding and social behaviour of lactating dairy cows. They reported that headlock barriers reduced the frequency of aggressive interactions at the feed-face, and allowed more equal access to feed during peak feeding periods. Bouissou (1970) found that divisions at the feeder separating the heads of adjacent individuals allowed subordinate cows to feed for longer periods of time (Endres et al., 2005). A similar, more recent, study to that of Bouissou (1970) carried out by Endres et al (2005) evaluated the effects of two feed barrier systems on feeding and social behaviour. Their results also reported that the divisions at the feeder separating the heads of side-by-side individuals allowed subordinate cows to have better access to feed. Cows performed fewer aggressive interactions at the feed-face when using the headlock compared with the post and rail barrier (5.5 vs. 6.9 displacements per cow per day; $t = 3.85$, $SE = 0.3$; $P = 0.03$).

(a)



(b)

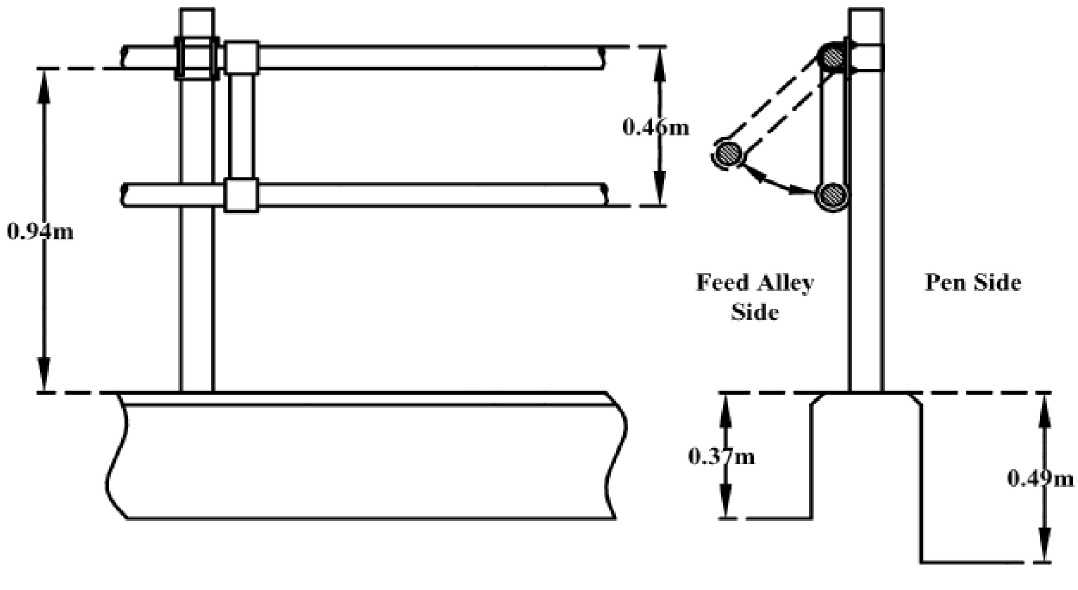


Figure 1.4 Front and cross-sectional views of a portion of the headlock (a) and post-and-rail (b) feed barriers.

1.4.1.1 Feed-face Length

It can be hypothesized that there is a critical space of feed-face length per cow, below which excessive competition occurs. It is probable that this critical length also varies with the group size and amount and availability of feed. The current British Standard Code of Practice for agricultural buildings states that cattle between the weights of 500-700kg require 600-700mm at feed face (DEFRA, 2006). However, if food is constantly available, as in ad-lib systems, these widths may be reduced by as much as 75%. It has been suggested that recommendations in this range are overly cautious, given that cows have had similar feed intake and milk production with space allotments much less than the recommended level (Friend and Polan, 1974; Friend et al., 1977; Menzi, Jr. and Chase, 1994). Dairy cows in North America are commonly housed in free-stall barns (cubicle housing) with approximately 0.6m of feed passage space per cow (Grant and Albright, 2001). Previous research on feeding space has suggested that cows can be kept with as little as 0.2m of feeding space per cow without adversely affecting DMI or milk production (e.g. (Friend et al., 1977; Collis, 1980)). In contrast, others have reported that increased competition at high stocking densities can limit the ability of some cows to access the feed-face at desired times i.e. when cows return from milking, and when fresh feed is offered (Huzzey, et al., 2006; Endres et al., 2005).

1.4.2 Choice Tests as a Novel Approach for Measuring Feeding Behaviour

As has been described above there are many traditional ways to monitor and describe feeding behaviour. For the purposes of this thesis, I proposed to approach the subject from the perspective of the experiences of individual cows, i.e. to develop a method that "asks" a cow what she wants at the feed-face. As discussed in Section 1.1 scientists have frequently used preference tests to establish animal's preferences for common housing conditions (although not usually for large animals such as cattle).

Preferences for different options of resources or environments can be assessed using choice tests of various kinds (Dawkins, 1983b). The broad principle behind the use of choice tests are that they provide an assessment of stimuli or contexts that the animal prefers or finds aversive (expressed as approach or avoidance behaviour). This, indicates how housing and management could be altered in ways that better suit the animal. The Y-maze or T-maze tests present two options at equal distances from the entry of the maze starting position, and usually involves animals being taught to anticipate a particular treatment if they enter one or the other arm of the maze. An animal is generally deemed as preferring an option if it spends more time with it, chooses it more often, or has a shorter latency to approach it (Bateson, 2004). Fundamental to this research is the assumption that animals make choices that are in their own best interests and that a knowledge of the preferences shown by animals will help us understand and improve their welfare (Frazer and Mathews, 1997). Hence, by giving animals the environments that they themselves must have chosen we should reduce suffering and consequently improve welfare (Bateson, 2004).

1.4.2.1 Criticisms of Choice Tests

Criticisms of preference testing have been the subject of several reviews (Dawkins, 1983b; Duncan, 1992; Fraser and Matthews, 1997; Bateson, 2004). The main points of these reviews will be summarised briefly in this section. Bateson (2004) highlights the two broad categories of criticisms of choice tests. Firstly, that they are only fulfilling short-term motivational priorities which may not produce long-term welfare, and secondly, that motivational priorities are not fixed. These points are valid and deserve some consideration. Many factors such as age, stage of reproductive cycle, time of day etc will all affect an animal's behaviour and motivational priority. The success of a choice test is strongly reliant upon the options offered to the test animals. For example, it has been suggested many times that a "preferred" option may still only be "the lesser of two evils". Duncan (1992) suggests two solutions to these problems. Firstly to provide a wide range of choices, so that animals are less likely to choose a "luxury" or "lesser of two evils". Secondly, to assess the strength of the preference using motivational testing. This involves assessing what the animal is "willing to pay" in terms of time expenditure or cuts in other areas of the animals normal time budget. Dawkins (1983b) has written extensively on the effect of previous experience of an animal on the results of a choice test. She goes on to describe that this can be controlled by controlling early experiences and the amount of exposure to each animal. In order to ensure the external validity of choice experiments it is important to use subjects that are in a state and environment as similar as possible to those of the captive animals whose welfare the aim is to improve (Mason et al., 1997).

1.4.3 Electronic Feeding Systems

Another method increasingly being used for monitoring feeding behaviour is by using electronic feeding systems. Feeding behaviour research can be time consuming due to the difficulty in manually collecting behavioural data at the time of feeding. In recent years various systems to record feeding behaviour have become commercially available. However, the success of these systems appears to be variable. DeVries et al (2003c) trialled an electronic system designed for unobtrusive monitoring of individual cows housed in a cubicle barn. The objective of the study was to validate the data generated by the system. The estimated number of meals consumed by each cow showed full agreement with meal frequency identified using video recordings. However, for each cow, the researchers found some instances in which the video showed a cow present at the feed passage, but the monitoring system failed to recognise it (12.5% of observations). The concept of using electronic systems is a very appealing and time saving one. However, further research into these devices and more sophisticated designs are required before they can replace or assist video recoding.

1.5 Conclusions

Key components in determining feeding behaviour are the social hierarchy, competition for feed, water, space and feed availability within a group of cattle. Feed accessibility could be the most important factor affecting an animal's ability to maximize feed intake due to high levels of competition. Feed should be available when cows desire to eat e.g. at sunrise or after milking. Adequate feed-face space for adult and growing cattle helps to ensure that feeding behaviour and total feed intake are optimised. Future research should focus on the relationships among feeding management, feeding space and barn design.

An individual's ability to control or cope with the social environment can affect not only its priority of access to resources such as food, shelter and mates, but also its state of health. The reaction of cattle to a production system can successfully be observed in terms of their behavioural response. In the case of lactating dairy cattle, understanding how to optimise feeding behaviour within a given feeding environment is crucial for making profitable dairy management recommendations.

1.6 Objectives

The overall aim of this review was to identify important gaps in the literature of dairy cow feeding behaviour. There is a lack of research investigating the extent of how the feeding environment can impact on social interactions, particularly by comparing different types of feed barrier, and assessing the extent of feed competition, specifically by low ranking animals. There is also a lack of research investigating the effect these factors on the individual cow, not just at group level. For these reasons the main aims of the project are to determine how key aspects of feed barrier design, such as spacing, barrier design and social hierarchy affects levels of aggression and feed intake in dairy cows.

CHAPTER 2

The Effect of Feeding Space on Aggression and Feed Intake in Dairy Cows

Abstract

Promoting feed intake of lactating dairy cattle is critical in terms of improving milk production, health, body condition and welfare of the animals. The main factors predicting feeding behaviour of an individual are its place in the social hierarchy, feed availability, and level of competition for feed and space. Reduced space availability has been shown to result in increased agonistic behaviours in cattle. The aim of this study was to observe behavioural interactions and feeding behaviour over 3 different feeding space allowances. It was hypothesised that as the space allowance increased the level of competition between individuals would decrease. Reduced competition should result in increased feed intake, reduced aggression and frequency of displacements. Forty-five multiparous lactating Holstein Friesian cows were used in the study and cows were allocated to 3 groups of 15 animals. Each of the 3 groups were exposed to 3 different feeding space allowances (0.35, 0.69, 1.04m) using a partial Latin square design. The space allowances (treatments) were chosen to represent low, standard, and high allowances. Each treatment lasted for a period of 9 days; however, the first 2 days were regarded as a habituation period. The cows experienced all 3 treatments in an order according to the partial Latin square design, lasting for a total of 27 days. Feeding and aggressive behaviours were continuously monitored using video cameras. Footage was analysed from two 60min periods per day, after cows returned from milking (peak feeding times). The number of feeding bouts was significantly higher at the greatest space allowance than for the two smaller allowances ($P<0.001$). The length of feed bouts decreased as the feeding allowance increased ($P<0.05$). The number of aggressive interactions decreased as the space allowance increased ($P<0.001$). The number of times individuals were displaced from the feeding area also decreased as the space allowance increased ($P<0.05$). There was a significant difference between feed intakes ($P<0.05$) with the largest space allowance resulting in the highest intake, however the standard space allowance produced the smallest intake, which did not confirm what was expected from the hypothesis. Milk yields were also significantly different ($P<0.05$) however, the largest space allowance produced the smallest yield. To achieve the maximum levels of feeding behaviour it is critical to fully understand all aspects of cattle

feeding behaviour. Adequate feeding space for adult growing cattle to comfortably feed side by side, helps to ensure that feeding behaviour and total feed intake are optimised for all animals in the group.

2.1 Introduction

Feed intake in dairy cows is directly related to milk production, therefore a good feed supply is extremely important to the modern, high yielding dairy cow. Promoting feed intake of lactating dairy cattle, particularly those in early lactation, is critical in terms of improving milk production, health, body condition and welfare of the animals (Grant and Albright, 1995).

Lactating dairy cows will spend between 3-5 hours per day feeding when provided with continuous access to a total mixed ration (Grant and Albright, 2000). They have the ability to consume feed extremely efficiently, however this may be affected by several factors, such as stocking density, feeding system design and apparatus, and attributes of the feed itself (e.g. physical appearance, quality etc).

Feed barrier (the physical divide between cattle and feed) design can have a major effect on feeding behaviour and feed intake, therefore it is important to consider when housing cattle and other livestock. Group feeding of cattle inevitably leads to a certain degree of competition, even when free access is available. Cattle interact in ways that might give some individuals advantages over others in the herd. Competition for feed can increase the rate of agonistic interactions and can also reduce feed intake, particularly of subordinate individuals. A limited feeding area most likely favours cows that are high in social rank. Cook et al (2004) suggested that dominant cows sort fresh feed, and that low-ranking cows with low feed access may be forced to alter daily activity patterns and feed at the feed-face only after dominant cows have fed. Therefore, providing equal access to fresh feed may be particularly important in reducing the variation in diet quality consumed by the cows (Endres et al., 2005).

Modern housing for farm animals frequently includes features designed to improve convenience for the stockperson by modifying animal behaviour (Tucker et al., 2006). For example, neck rails (part of the cubicle design) help to keep cubicles clean by preventing cows from standing with all four hooves in the cubicle (Tucker et al., 2005). Present economic circumstances may force some livestock producers into raising animals in large groups and at high stocking density. These factors reduce labour and building costs, but also influence behaviour and production performance (Kondo et al., 1989). When cattle are stocked at high densities, it becomes very difficult for animals to avoid violation of inter-individual distances; consequently there is an increase in the level of agonistic interactions. The role of space during feeding is important since it has implications for both production (related to feed intake) and housing design (Manson and Appleby, 1990).

Reduced space availability has been shown to result in increased agonistic behaviours in cattle (Kondo et al., 1989), perhaps limiting the ability of some cows to feed at the preferred feeding times. In situations where competition is expected (e.g. limited space and feed), restricted feeding behaviour may compromise cow productivity (Friend et al., 1977; Friend and Polan, 1978). A highly competitive time at the feed-face coincides with the return of cows from milking and when fresh feed is offered (Friend and Polan, 1974).

The current UK recommendations from the Department for Environment, Food and Rural Affairs (DEFRA) suggests that if animals are expected to feed simultaneously, the feed-face required per cow is dependent upon the size of the animals (DEFRA, 2006). Cows between 500-700kg require 0.6 – 0.7m. However an amendment to this information suggests that if feed is available *ad libitum* the feed-face allowance may be reduced by as much as 75%. Other studies have suggested that recommendations in this range (0.6 – 0.7m) are overly cautious, given that cows have had similar feed intake and milk production with space allotments much less than the recommended level (Friend and Polan, 1974; Friend et al., 1977; Menzi, Jr. and Chase, 1994). In contrast, others have reported that increased competition at high stocking densities can limit the ability of some cows to access the feed-face at desired times i.e. when cows return from milking, and when fresh feed is offered (DeVries et al., 2004; Huzzey et al., 2006). Additionally the National Dairy Farm Assurance Standards (NDFAS), which is a scheme to which the vast majority of UK dairy farmers belong, also make some recommendations. They state that “all feed and water provided for dairy cattle must be of an appropriate quality for a properly balanced diet and be available to all animals” (NDFAS, 2008). However, the language used is fairly ambiguous due to a lack of actual specifications, therefore the recommendations are easily open to interpretation by the individual producer.

The aim of the present study was to observe behavioural interactions and feeding behaviour over 3 different feeding space allowances. The middle space allowance was chosen as it is the standard length recommended for dairy farms within the UK, while the other 2 allowances were markedly smaller and larger than the average. It was hypothesised that as the space allowance increased the level of competition between individuals would decrease. Reduced competition should result in increased feed intake, reduced aggression and frequency of displacements.

2.2 Materials and Methods

2.2.1 Housing Area, Animals and Management

Forty-five mid-stage lactation Holstein Friesian cows of high genetic merit were used in the study. All of the cows were multiparous (parity = 4 $\pm$ 1.9; mean $\pm$ SD). They were housed in a cubicle shed at Crichton Royal Farm, SAC Dairy Research Centre, Dumfries, Scotland. Cows were allocated to 3 groups of 15 animals, and were balanced across the groups for age, stage of lactation and milk production levels. The groups were housed in 3 adjacent pens and 2 groups had access to 15 bedded cubicles and 1 group had access to 16 cubicles (this extra cubicle was due to building design and did not alter the feed-face space availability). Each cubicle stall had a space allowance of 200 x 130 x 100cm. Cows were fed a TMR consisting of grass silage (60%), mix (11%) grain maize (17 %), lupins (5%) alkalage (6%), and minerals (1%) on a fresh weight basis. The mix contained wheat (45%), sugar beet pulp (45%), soya (5%) and wheat dark grains (5%). Fresh feed was provided once daily at approximately 09.00h, and cows were fed using a post and rail feed barrier. Feed was pushed up daily at approximately 05.00, 17.00, and 21.00h. Cows had *ad libitum* access to water and were milked twice daily at approximately 05.00 and 14.00h.

2.2.2 Experimental Design and Treatments

Each of the 3 groups experienced 3 different feeding space allowances, using a partial Latin square design. The space allowances (treatments) were chosen to represent low, standard, and high allowances. These treatments corresponded to 0.35m, 0.69m and 1.04m per cow. The cattle were grouped and housed in equal space allowances for a period of 14 days before the treatments began. Each treatment lasted for a period of 9 days; however, the first 2 days were regarded as a habituation period, to allow the cows to settle into the new space allowance. The cows experienced all 3 treatments in an order according to the partial Latin square design, lasting for a total of 27 days. When a new treatment began, the cows remained in their group pen and gates along the passages were moved to alter the feed space allowances of the pen.

2.2.3 Measurements

2.2.3.1 Monitoring Behaviour

Feeding and aggressive behaviours at the feed-face were recorded during the last 7 days of each space allowance treatment. All behaviours were continuously monitored using 13 video cameras (Panasonic). Cameras were connected to a video multiplexer (Dedicated Micros, Sprite Lite) and a 12 hour time-lapse video cassette recorder (Panasonic Time Lapse Video Cassette Recorder AG-6124). The cameras were placed approximately 2m above the feed barrier, and they were positioned to view both the feed-face and the alley. Cows were identified using unique alphanumeric symbols painted onto their backs with non-toxic external paint.

2.2.3.2 Measuring Aggressive Behaviour

The number of displacements per cow was used to measure the competitive behaviour of cows at the feed-face. A displacement was noted when a cow's head (actor) came in contact with a cow that was feeding (reactor), resulting in the reactor withdrawing its head from the feed-face, as described in (Huzzey et al., 2006). The type and frequency of aggressive behaviour was also recorded using an ethogram (Table 2.1).

Behaviours were recorded during the 60 minute period after the delivery of fresh feed and after the afternoon milking. The appearance of the last cow in the pen marked the beginning of these observation periods. These two recording periods were selected as they have been shown to be the times when most cows are present at the feed-face and when there is the highest level of competition (DeVries et al., 2003b).

Table 2.1. Ethogram of agonistic behaviours while cattle are at the feed-face

	ACTOR	*Description*
P	Pushing	The actor uses some part of the body other than the head to attack or displace the recipient.
B	Bunting	The actor uses the head to attack or physically displace the recipient. This involves physical contact between the two individuals.
BL	Blocking	The actor uses the body to physically block the recipient/subordinate from gaining access into the feed-face.
T	Threatening	The actor engages in a threatening swing of the head in the direction of the recipient, no contact occurs between the two individuals.
BD	Bulldoze	The actor forcefully enters the front of the feed-face displacing more than one individual.
G	Groomed	The actor is groomed
PT	Penetrate Feeder	The actor penetrates the line at the feed-face resulting in physical contact with cows on both sides.

2.2.3.3 Feeding Behaviour

Using the same video footage that was described previously, feed bout length was recorded for each individual. A ‘bout’ was described as beginning when the cow had her whole head under the strap of the feeder, and the time was not stopped until she fully stepped away from the barrier. If she moved away from the barrier for less than a 10 second period then it was recorded as being the same feeding bout. This criterion was chosen after reviewing a sample of video footage from the feed-face.

Movements during bouts appeared to be very brief (i.e. 1-2 sec) unless the animal was moving away from feed barrier altogether or to a different location.

2.2.3.4. Feed Intake and Milk Yield

Each group was given an equal weight of TMR and the refusal was weighed on day 3 and day 7 of each treatment (partly due to normal farm practices). Barriers were designed to prevent silage mixing between the different groups of cows. Boards were also designed to block off an area equivalent to the space allowance of one cow in case of illness (which happened on one occasion during the final days of the study). This was considered to be more efficient than replacing a sick or lame cow as groups were balanced at the beginning of the study. Milk yield was recorded on the last 3 days of each treatment.

2.2.4 Statistical Analyses

Genstat (GenStat®, 7th Ed., Lawes Agricultural Trust, VSN International Ltd., Oxford, UK) was used for all statistical analyses. One-way analysis of variance (ANOVA) models were fitted to almost all of the behavioural data to identify any potential significant differences between treatments (space allowances), and 'pen' was considered the experimental unit. Data were tested for normality and transformed (square root) to normalise them where required. The milk yield and feed intake data were already normally distributed and an ANOVA model was used to analyse them. The treatment structure was entered into the model as *space allowance,* and it was blocked by an interaction between *cow* and *period of time*. A Restricted Maximum Likelihood (REML) linear mixed model was used to analyse the length of feed bout data. Space allowance was fitted as a fixed effect and cow I.D and period was fitted as random effects within the model.

2.3 Results

As the space allowance increased the frequency of aggressive interactions decreased significantly ($P<0.001$). Additionally, the frequency with which cows were displaced from the feed-face also declined ($P<0.05$) as the length of feed-face increased (Table 2.2). The number of feeding bouts significantly increased when they were provided with 0.35m or 0.69m compared with 1.05m per cow (Table 2.2). However, the number of feeding bouts did not significantly differ between the 0.35m and 0.69m per cow allocations. The length of bouts decreased significantly as the space allowance increased.

Table 2.2 Measures of feeding and aggressive behaviour* with 0.35m, 0.69m, 1.04m, of allocated feed-face space per cow. Data are expressed as means.

Measurements**	***Treatment***				
	0.35m	***0.69m***	***1.04m***	***S.E.***	***P***
Number of Bouts	2.0	2.0	2.5	0.25	<0.001
Length of Bouts (s)	1285	1146	1036	82.18	<0.05
Aggressive Interactions	0.9	0.6	0.3	0.27	<0.001
Displacements at feed-face	0.4	0.4	0.2	0.20	<0.05

* Data were averaged for the 7 d per treatment for 3 groups of 15 cows.

** All behaviours recorded for 60 minutes after delivery of fresh feed and return from afternoon milking.

There was a significant difference between milk yields of the largest space allowance compared with the other two space allowances, with the largest space producing the smallest yield. This result does not follow the pattern that would be expected from the hypothesis. It is likely that the length of treatments was not sufficient enough to see a significant change in milk yield.

Table 2.3 Measures of milk yields feed intakes & weight with 0.35m, 0.69m, and 1.04m of allocated feed-face space per cow. Data are expressed as means.

Measurements**	***Treatment***				
	0.35m	***0.69m***	***1.04m***	***S.E.***	***P***
Milk Yield (Kg)*	30.2	30.2	29.6	0.7	<0.05
Feed Intake (Kg)**	637.3	605.3	662.3	23.0	<0.05

***** Mean total of individual yields per day

****** Mean total of feed intake for pen of animals per day

2.4 Discussion

As the space allowance increased, the number of aggressive interactions and displacements both decreased. These results suggest that the increase in space allowance results in less competition between individuals. Huzzey et al (2006) observed that the number of times that cows were displaced from the feeding area increased in a curvilinear manner as stocking density also increased (0.21, 0.41, 0.61, 0.81 m/cow), particularly at the smallest space per cow. Similar results have also been found by DeVries et al (2004) and Oloffson (1999). DeVries et al (2004) observed 53% fewer aggressive interactions when space allowance at the feed-face was increased from 0.5m to 1.0m per cow. Little is known of the long term effects of cattle being raised in these competitive environments, specifically, the effect on health and production. In a preliminary study (Leonard et al., 1998), it was suggested that cows that engaged in a high number of aggressive interactions at the feed-face had more severe claw-horn lesion scores than those that did not engage in such encounters. Furthermore, during the first few weeks after calving, cows may be particularly vulnerable to disease, and overstocking leads to increased competition (Grant and Albright, 1995). Oloffson (1999) suggested that when dairy cow facilities are being designed, a limited feeding area might actually be profitable and recommendable if the increased competition for feed does not harm the welfare of the animals or affect production negatively. However, as the present study and the other previous research has reported, a limited feeding area is likely to increase competition and aggressive interactions; so it is highly unlikely that increased competition will not, at least to some degree, negatively affect welfare. Further studies should be designed to determine the long term effects of competition on measures such as DMI, milk production, claw health and disease incidence. The behavioural data also highlighted that as the feeding space increased, the number of bouts also increased and the length of bouts decreased. This suggests that cows prefer to feed in frequent, short bouts which support the findings of Grant and Albright (1995) and that larger space allowances support this feeding pattern.

When provided with extra space at the feed-face, cows did not increase their feed intake as hypothesised. The largest space allowance of 1.04m per cow was shown to have the greatest intake; however, the standard allowance (0.69m per cow) had the lowest intake. A likely explanation for this result is that differences in feed intake did occur between individual animals, although, these are masked by the overall group effect. In spite of any restriction at the feed-face, the most dominant cows will always gain access to feed. Therefore, an effect may be observed among the more submissive cows. A review by Albright (1993) suggested that when a competitive situation exists at the feed-face, dominant cows tend to spend more time eating than cows of lower social rank. Friend and Polan (1974) found that this led to a situation where there was greater intake of feed by dominant individuals than that of submissive. For cows that are not able to gain access to feed at peak feeding times, they may be forced to shift their feeding times to other times of day, including late at night (Forbes, 1995). Another possible explanation for the unexpected feed intake results are that at 0.35m per cow, the increased level of competition could have led to some individuals spending more time at the feed-face eating, whilst defending their space. This could have led to increased intakes compared to the standard space allowance of 0.69m per cow.

Other studies have shown that cows spend less time feeding when they have less available feeding space (Oloffson, 1999; DeVries et al., 2004), however these studies were not designed to test multiple levels of feeding space (Huzzey et al., 2006). Friend et al (1977) tested several different stocking densities. However, they only observed a significant decline in feeding time and DMI at the smallest space allowance per cow (0.1m of feed-face per cow). This is less than one third the size of the smallest allowance used in this study. Perhaps a more significant difference would have been detected if smaller space allowances have been used, although this may pose a serious welfare concern to the animals and would be unlikely to receive ethical approval. Another important point to note is that Friend et al (1977) only used a small number of animals and the treatments were not replicated.

Although there was also a significant difference between milk yields of each treatment it was not a large difference. For the low and standard space allowances the combined milk yields were extremely similar 30.2kg (± 0.6; 0.8 respectively) with only a minute difference with the largest space allowance (29.6kg) (Table 2.3). The most probable reason for this is that length of treatment was not long enough, perhaps a period of ~ 21 days would show a more distinctive effect of the treatment. The cows used in this study were also reasonably high yielding, perhaps lower yielding cows would have shown more diverse results. Friend et al (1977) suggested from their study that the reason for not observing changes in milk yield were because periods of competition at the feed-face were brief. As the feed intakes did not alter as expected it is possibly due to lower ranking animals feeding at non optimal times (i.e. outside peak feed times).

To achieve the greatest intensity of feeding behaviour it is critical to fully understand cattle feeding behaviour. Results from this study suggest that increasing space at the feed-face should facilitate normal feeding patterns i.e. cows feeding in frequent, short bouts, and reduce aggression.

2.5 Conclusions

By providing more space at the feed-face, cows were able to access feed at peak feed times. More space led to fewer aggressive interactions and fewer displacements at the feed-face. At the larger space allowances the number of bouts increased and the length of feeding bouts decreased, which has previously been described to be the most optimal feeding pattern. Adequate feed-face space for adult growing cattle helps to ensure that feeding behaviour and total feed intake are optimised. In order to reduce aggressive behaviours and displacements at the feed-face, a space allowance in the region of 1m/cow is recommended.

CHAPTER 3

Dairy cows trade-off feed quality with proximity to a dominant individual in Y-maze choice tests

Abstract

In this experiment choice tests were used as a tool to determine how dairy cows perceive their feeding environment with specific emphasis on understanding the challenges that low ranking animals face when forced to feed in the presence of socially dominant cows. It was hypothesised that cows would trade-off proximity to a dominant individual at the feed-face with access to food of a high quality. Thirty Holstein Friesian cows were used in the study. A test pen contained a Y-maze, with one black feed bin placed in one arm of the maze and one white feed bin placed in the other arm. During a training phase half of the cows were trained to make an association between the black bin and high quality food (HQF), and the white bin and low quality food (LQF). The other half was trained with the opposite combination, to prevent any colour bias. The status of each cow was assessed and dominant and subordinate cows were paired. Choice test 1 determined if cows had correctly learned the association between colour (of food bin) and food quality. Cows were presented with one black and one white bin in the two arms of the maze, with the presentation of each coloured bin in the left and right arms randomised. When cows achieved an 80% success rate of HQF preference they proceeded onto the next stage, where two further tests were presented. In choice test 2, the subordinate cow was presented with two bins of HQF, one of which had a dominant cow feeding from it. In test 3, cows had a choice of HQF & LQF, with the dominant cow present at the HQF bin. Cows showed a significant preference for feeding on HQF alone rather than next to a dominant ($P<0.001$). When they were "asked" to trade-off feed quality with feeding next to a dominant, the majority of cows chose to feed alone on LQF ($P<0.01$) These results suggest that social status within a herd could significantly affect feeding behaviour, especially in situations of high competition and for subordinate individuals.

3.1 Introduction

In recent years there has been an increasing concern over the issue of farm animal welfare. One reason underlying this concern is the belief that many modern livestock production systems do not allow animals to perform a natural range of behaviours leading to a possible decline in welfare. One method of determining the importance of these behaviours is to perform choice tests. The results of such assessments are useful for making recommendations regarding animal husbandry, and thus, aiming to improve animal welfare (see Dawkins 1980, and Dawkins 1983b, for a review). In this study, choice tests were used to assess feeding behaviour in dairy cows.

Feed intake in dairy cows is directly related to milk production, particularly the dry matter intake (DMI) which is the main factor contributing to production. A good feed supply is particularly important to the modern, high yielding dairy cow and insufficient quality or quantity of feed can lead to excessive weight loss and associated health and welfare problems. In the UK, advances in genetics and improved management practices have resulted in a rapid increase in milk production. The current average yield in the UK is around 7,000 litres per cow per annum (Dairy Co, 2007). This figure is almost seven times the required volume of milk of a cow suckling a calf. This massive increase in milk yield has led to dairy cows having considerably increased nutrient requirements in order to maintain these levels of production.

A well-designed management system should adequately accommodate optimal feeding behaviour i.e. cows prefer to eat in frequent, short bouts (Grant and Albright, 1995) during specific times of day (on return from milking and after delivery of fresh feed). However, the intensification of dairy production systems has resulted in animals often competing for resources (Albright, 1993). Factors that appear to limit access to feed include not only physical aspects (i.e. building design, feed barrier etc) but also social factors. Social dominance has practical importance if dominance relationships result in certain animals consistently losing out on access to important resources (Grant and Albright, 2001). Competition for feed can increase the rate of agonistic interactions and can also reduce feed intake of certain individuals. Factors that influence the level of competition include manipulations of management e.g. *ad libitum* or restricted feeding (Olofsson and Wiktorsson, 2001), feeding frequency (DeVries et al., 2005; Oostra et al., 2005), grouping (Grant and Albright, 2001), design of facilities (Collis et al., 1980; DeVries et al., 2004), stocking rate (Huzzey et al., 2006), and equipment, such as partitions (Herlin and Frank, 2007). A restricted feeding area most likely favours cows that are high in social rank. The consequences of experiencing high levels of competition at the feed-face could result in subordinate animals altering their daily activity patterns in order to maintain adequate levels of feed e.g. spending less time ruminating and lying, and increasing the length of feed bouts which can increase the risk of metabolic disorders. Social stress, such as over crowding and excessive competition for feed, can significantly reduce rumination activity (Batchelder, 2000). Dominant cows may also sort the total mixed ration preferring the grain concentrate component and leaving less desirable forage components (DeVries, 2005). Sorting can reduce the nutritional quality of the remaining feed which would then be consumed by lower ranking individuals feeding outside of peak feeding times. Cows that are unable to access the feed-face at peak feeding times may not maintain adequate nutrient intake to meet their energy requirements (Hosseinkhani et al., 2008).

By observing and understanding how cows behave at the feed-face it should be possible to design a feed barrier (the physical divide between cattle and feed) that reduces competition and maximises feed intake. Previous approaches have largely involved group studies (e.g. Friend et al 1977; Huzzey et al, 2006; Kondo et al, 1989 and Lang et al, 2007) focussing on the effects of stocking density on aggressive interactions. This study uses a choice test approach to study the choices faced by cows at the feed-face. Choice tests require animals to choose between two or more different options or environments (Fraser and Matthews, 1997). In dairy cows, choices relating to various treatments, including feeding, shouting, electric shock, hitting (Pajor et al., 2003) and being milked (Prescott et al., 1998) have been assessed using Y-maze test methodology. This process involves training individual animals to anticipate receiving a treatment if they enter one arm and an alternative treatment if they enter the other arm (Pajor et al., 2003). An animal is generally thought to prefer an option if it spends more time with it and/or chooses it more often.

In this instance, choice tests were used as a tool to determine how dairy cows perceive their feeding environment with specific emphasis on understanding the challenges that low ranking animals face when forced to feed in the presence of socially dominant cows. It was hypothesised that cows would trade-off proximity to a dominant individual at the feed-face with access to food of a high quality.

3.2 Materials and Methods

3.2.1. Animals and housing

Forty-two mid-stage lactation Holstein Friesian cows of high genetic merit were used in the study. Twelve cows were used as part of a pilot study, and three groups of ten were used for the actual experiment. Half of the cows were multiparous (parity = 3.4 $\pm$ 0.5; mean $\pm$ SD) and half were primiparous. All cows were housed in a cubicle shed at the SAC Dairy Research Centre, Dumfries, UK. Animals were separated from the rest of the herd 24 hours before experimental procedures began. They were housed in a separated area of the cubicle housing within the main shed where they had access to feed and water. After testing sessions, animals were returned to the cubicle area where they had access to a total mixed ration formulated to provide adequate nutrients for maintenance and milk production. The animals were not fed any additional concentrates during milking. Fresh feed was delivered once a day (whilst the animals were being tested in a separate area) and they generally had access to it within about 1 hour of their normal feeding time.

3.2.2 Test procedure and testing arena

All testing was carried out between the hours of 08.00 and 12.00. After morning milking the cows were taken to a large straw holding pen, situated next to the test pen. The cows remained in this holding pen with free access to water but with no access to feed until the testing sessions were complete. When each cow was to be tested, in a random order, they were moved individually by a handler from the holding pen and held at the top of the passage. The cow was allowed to walk down the full length of the passage (~30m) towards the test pen. The animals were not rushed and they were only given gentle encouragement if they did not make their way in the correct direction. Two handlers were present during all sessions. Handlers all wore the same colour of overalls and stood in the same positions for each test (outside the test area).

The Y-maze was inside the test arena (Figure 3.1) and consisted of a single alley (1.2m long) with two arms (3.65m long), one to the left and one to the right. At the end of each arm either a black or white feed bin (0.75m x 0.55m x 0.58m) and a sheet of plastic of corresponding colour mounted on the wall (0.60m x 0.45m). Both boards were visible to the cow as she entered the Y-maze arena. The arms of the maze were not formally penned off. Instead, the shape was defined using plastic crates to form the base of the ‘Y’, with the position of the feed bins representing the arms. The walls of the test pen were made from brick and solid wood so that animals in the pen were visually isolated from pen-mates and other distractions within the shed. The arena was classified as having 3 separate zones so that the location of the cows could be recorded during testing.

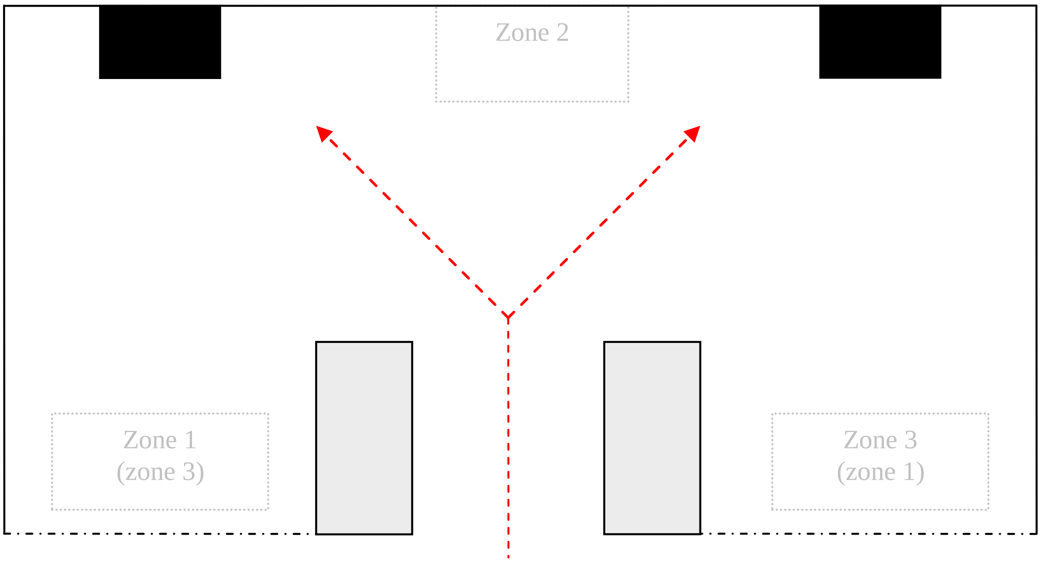


Figure 3.1 Diagram of test arena, including starting entrance, 3 zones and position of feed bins.

NB. Although this is referred to as a Y-maze, please note that there are no formal divisions of the arms of the Y-shape.

3.2.3 Dominance Testing

Animals were allocated to pairs consisting of a dominant and subordinate animal. To assess the dominance of each cow an index was constructed from interactions observed at the feed-face in the cubicle area. Displacements were recorded at a post and rail feed barrier during the 30 minute period after the delivery of fresh feed and after the afternoon milking for 5 consecutive days. These two recording periods were selected as they have been shown to be the times when most cows are present at the feed face and the highest level of competition occurs (DeVries et al., 2003b). A displacement was noted when a cow's head (actor) came in contact with a cow that was feeding (reactor), resulting in the reactor withdrawing its head from the feed face, as described in Huzzey et al (2006). The number of displacements per cow was used to measure the competitive behaviour of cows at the feed face. These observations were used to calculate an ‘index of success’ from agonistic interactions of each individual cow using the methods described by Mendl et al (1992) (Figure 3.2). This was calculated by dividing the number of cows that an individual was able to displace, by the number of cows that and individual was able to displace plus the number of cows that were able to displace the individual, all multiplied by 100. This method has previously been used to assign dominance in a number of cattle and pig studies (Mendl et al., 1992; DeVries et al., 2004; DeVries and von Keyserlingk, 2006). From within each group of 10 animals, cows were assigned a rank from 1 to 10 with 10 being the most dominant. Aiming to maintain a significant level of dominance between pairs, cows were paired 10-5, 9-4, 8-3….etc. In cases where observations did not resolve dominance, pairs were presented with a line of concentrate feed in an open space. Aggressive interactions were recorded and the success index was calculated.

$$\boxed{\frac{\text{Number of cows that an individual is able to displace}}{\begin{array}{l}\text{Number of cows that an individual is able to displace +}\\ \text{number of cows that are able to displace the individual}\end{array}} \quad \text{x } 100\%}$$

Figure 3.2 Calculation for ‘index of success’ Mendl et al (1992).

3.2.4 Training procedure

The training phase consisted of four consecutive days, followed immediately by a testing period of two to four days. All of these procedures were carried out in the same test arena. Half of the cows were randomly assigned to be trained to associate a black feed bin as containing high quality food (HQF) and a white bin as containing low quality food (LQF). The other half was trained with the opposite combination. The HQF was a concentrate pellet, and the low quality feed was a mix of rolled barley (82%) and soya (18%). These feeds were chosen as they have been acknowledged to be of high and low palatability, but have similar levels of metabolisable energy (ME) and crude protein (CP). Concentrates are highly valued by cows and are therefore a cause for competition and aggression (Herlin and Frank, 2007). The feed chosen was also familiar to dairy cows, as it is a component of their regular TMR. This familiarity prevented the introduction of any novel foods that might alter feeding behaviour due to neophobia. Both dominant and subordinate cows were trained, even though it was only the subordinate cows that were going to be tested. This allowed all of the cows to become familiar with the arena and equipment.

The cows were individually brought into the test arena and presented with only one bin of either high or low quality feed, in either the black or white bin, on the right or left hand side of the pen. These presentations were in a randomised order to prevent animals from predicting choices. Each cow had two non-consecutive training tests per day for eight days, each of which lasted for a period of about five minutes (this was the average length of time it took to consume the 0.5kg meal).

3.2.5 Testing procedures

3.2.5.1 Test for association between feed quality and bin colour (choice test 1).

After training, the animals were tested to evaluate if they could correctly make an association between the feed quality and the colour of the bin. Each cow was presented with both feeds together (on either arm of the ‘Y’) to determine if they could consistently choose the bin containing the high quality feed. Their choice was recorded as being the bin they took the first mouthful of feed from. Cows were removed after they had either finished the feed from the bin of their choice (either high or low) or the five minute time limit had elapsed. If an animal had made a wrong choice initially, then moved to feed from the correct feed bin before 3 minutes, they were given a limit of 30 seconds to feed before being removed from the arena. However, if they changed their decision after three minutes, they were removed from the pen immediately. The aim of this criterion was to allow cows to correct their choice (within 3 minutes) if they initially approached the wrong bin, but to prevent animals learning that eating both feeds was an option. If a cow initially chose the wrong bin and moved within 3 minutes, this was still counted as an ‘incorrect’ choice.

3.2.5.2 Choice test between feeding alone or next to a dominant

The second choice test involved the subordinate cows being presented with a bin of HQF at both arms of the Y-maze, one of which had a dominant cow feeding from it. The amount of time that a subordinate cow spent in each area of the arena was also recorded. The aim of this was to identify if subordinate cows were actually choosing to feed alone or if they were being blocked by the dominant cow. The test arena was split into three zones (Fig 3.2). These zones represented the side the dominant cow was occupying (1), the middle area (2), and the unoccupied area (3). Each cow was tested 4 times over 4 days, and the location of the dominant cow was randomised over the trials.

3.2.5.3 Trade-off choice test between feed quality and proximity to a dominant

The third choice test offered a trade-off situation between feed quality and proximity to a dominant individual. Subordinate cows had to make a choice between HQF and LQF, with the dominant cow present at the HQF bin. Each cow was tested 4 times also over 4 days, and the location of the dominant cow was also randomised.

3.2.6. Data collection and statistical analyses

For each choice test the number of times an individual cow chose each option was recorded. Sign Tests were used to test for a significant difference between the number of times a cow chose to feed alone and the number of times she chose to feed with a dominant cow ($P<0.001$). Wilcoxon Signed Ranks Tests were used to test the significance of the difference between the choices made in choice test 2 and choice test 3 ($P<0.05$).

3.3 Results

In choice test 1, all cows were tested to determine if they could correctly and repeatedly chose the high quality food, when offered both qualities at the same time. The number of tests for individuals to reach the criteria of 8 consecutive correct choices from 10 testing sessions is displayed in Figure 3.3. One pair from each group of 10 that did not reach the criteria was dropped from the entire study. Cows showed that they had been successfully conditioned to associate colour with feed quality, and that they preferred the concentrate pellets (HQF) to the barley/soya mix (LQF).

For choice tests 2 and 3, the number of times an individual cow chose LQF or HQF (in the left or right arm of the Y-maze) was recorded (Figure 3.4 and 3.5). The majority of cows (75%) always chose to feed on HQF alone rather than next to a dominant individual. Only 2 cows chose to feed alone in 3 out of the 4 trials, and 1 cow chose to feed alone in 2 out of the 4 trials. Figure 3.5 shows the results of the trade-off choice (choice test 3) between feed quality and proximity to a dominant cow. Sixty-seven percent of cows always chose to feed alone on LQF. Twenty-five percent chose to feed alone 3 times out of 4 trials and 1 cow always chose to feed next to the dominant cow on HQF.

Cows preferred (Table 3.1*)* feeding alone rather than next to a dominant when they were offered high quality feed on both sides of the Y-maze ($P<0.001$). They also showed a significant preference when they were “asked” to trade-off food quality and proximity to a dominant cow ($P<0.01$). A Wilcoxon Signed Ranks Test was performed between the choices made from test 2 and test 3 (Table 3.2). Choice test 2 acted as a baseline, identifying that cows would rather feed alone than next to a dominant cow regardless of feed quality. There was no significant difference ($P>0.01$) in preference in choice test 3 i.e. even in the trade-off situation, cows still chose to feed alone. The amount of time that a subordinate cow spent in each zone of the arena was also recorded. Subordinate cows spent 83% of their time standing alone in the test arena, 5% of time was spent in the middle, and 12% was spent standing in the same side as the dominant cow.

Table 3.1 Sign Tests for difference between choices of each choice test.

	N	**Below**	**Equal**	**Above**	**P**
Choice Test 2	12	0	1	11	< 0.001
Choice Test 3	12	1	0	11	< 0.01

Below refers to the number of cows that chose to feed with the dominant cow more often. *Equal* refers to the number of cows that chose both options an equal number of times. *Above* refers to the number of cows that chose to feed alone more often.

Table 3.2 Wilcoxon Signed Ranks Test for differences between choices over both choice test 2 and choice test 3.

Test	**N**	**Z**	**P**
Choice Test 2 & 3	12	8	> 0.05

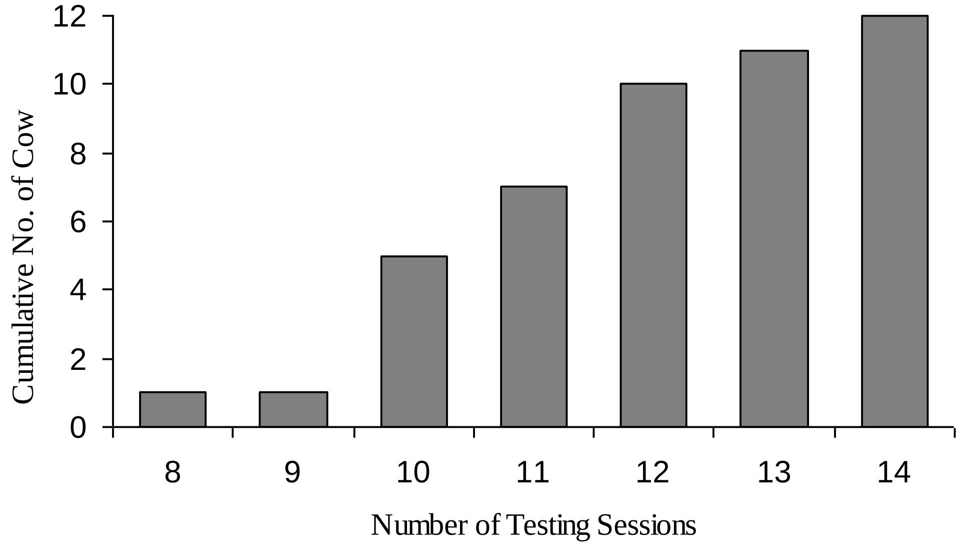


Figure 3.3 Choice test 1: Cumulative number of cows that reached success criterion of 8 correct choices out of 10 in consecutive sessions.

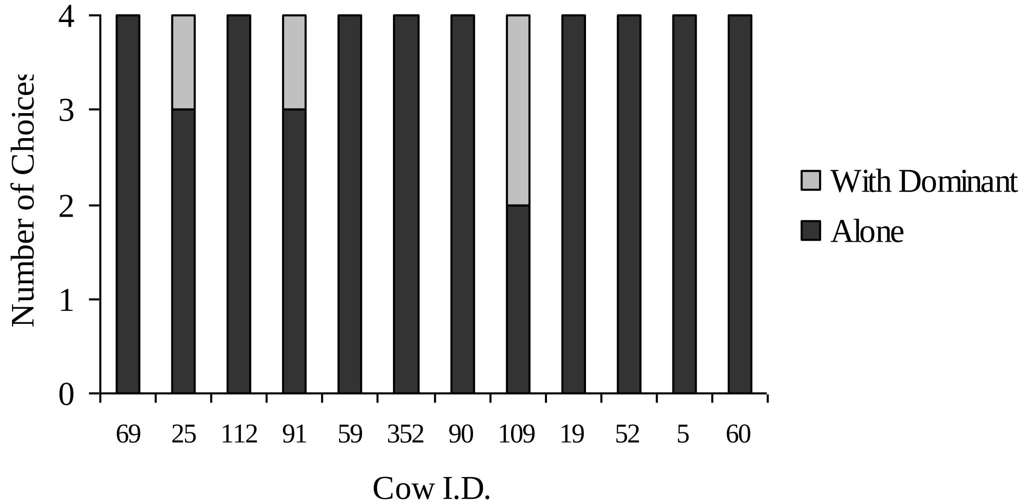


Figure 3.4 Choice test 2: subordinate cows given choice of feeding on high quality food alone or next to dominant cow.

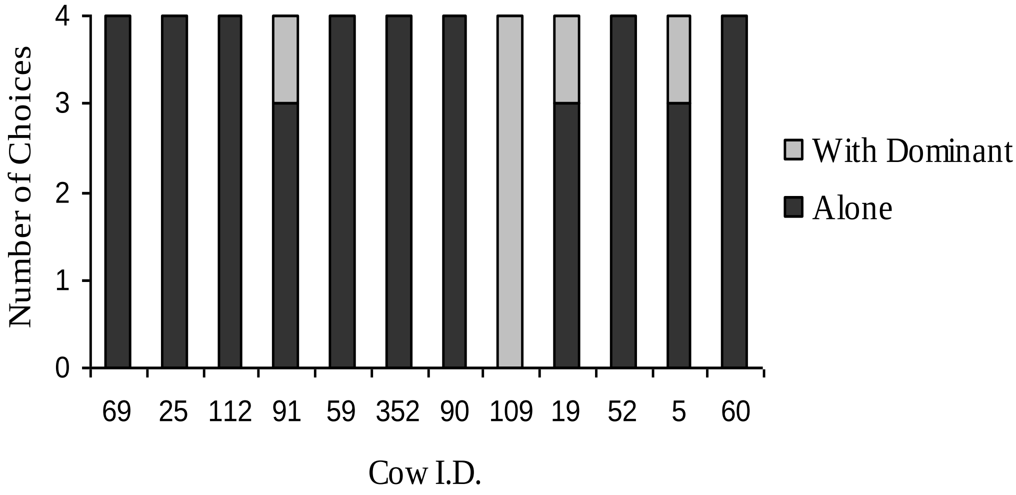


Figure 3.5 Choice test 3: subordinate cows given choice to trade-off feed quality with feeding alone or next to dominant cow.

3.4 Discussion

Low status cows showed a marked preference for feeding alone rather than next to a dominant individual. Low status cows also traded-off food quality for feeding alone rather than next to a dominant cow. The purpose of the choice test was to examine the importance of social status of herd mates is on feeding choices. Choice test 2 involved the test animals receiving the same quality of feed at both arms of the Y-maze, therefore the results suggest that the presence of the dominant cow must create a considerable level of influence over the choice. For the trade-off test (choice test 3), cows are ranking social pressure of the presence of a dominant, even more important than food quality, despite the obvious importance of nutritional intake. The results suggest that proximity between individuals is an important factor whilst feeding, especially for low status cows. Previous studies have also shown that when provided with more space at the feeder, cows increased distances from their nearest neighbour, reduced their frequency of aggressive interactions, and increased feeding activity (DeVries et al, 2004). The large majority of cows in the study agreed in their preferences. Almost all of the cows trained in the study succeeded in learning the association between colour and feed quality with relative ease. Similar successful learning performances have been reported in cows before (e.g. Pajor et al., 2003; Arnold et al., 2007) supporting the effectiveness of this type of approach with this farm species.

There were occasions when cows did not choose to trade-off feed quality and one individual never did this. There is no clear explanation for these events; however some individual variation in relative social dominance within the pair is to be expected, perhaps due to underlying factors such as pre clinical disease affecting social or feeding behaviour or due to the high possibility of a non-linear hierarchy.

The percentage of time that a test cow spent in specific zones of the arena was recorded to determine if cows were actively choosing to feed from their preferred bin, or the dominant cow was aggressively preventing access. Over all of the test period 83% of cows remained within the area of their chosen feed bin. Twelve percent of the overall time spent in the test arena was spent in the same zone as the dominant cow. The distribution of locations suggest that most cows always chose to feed alone, and only on a few isolated occasions would a low status cow not feed with the dominant because she was physically restricted from doing so by the dominant herself.

Y-maze tests are a widely used tool for assessing animal welfare; however they have generally been restricted to smaller species such as rodents and chickens probably due to easier manoeuvrability of the animals and the apparatus being easier to construct and set-up. There are only a very limited number of studies using this method with cattle (Grandin et al., 1994; Hosoi et al., 1995; Prescott et al., 1998; Pajor et al., 2003) and never before to look at the effect of social dominance at the feed-face. The options offered within this experiment reflect a realistic situation of the social pressure that cows experience on a daily basis whilst feeding. They were chosen to replicate a normal feeding environment, hopefully avoiding the potential pitfalls of offering the wrong options in a choice test.

Testing animals individually, as in this study, allows greater control over the delivery of treatments compared to testing individuals in a group situation. Testing individuals as part of a feeding behaviour study in a group situation may not always allow all animals to have the same access to feed due to social and physical restraints. There is a comprehensive body of literature explaining what happens when various aspects of the feeding environment are manipulated, however, the present choice test approach is very complimentary in explaining what is happening at cow level. This approach has the potential to explore hypotheses raised in other feeding behaviour studies to provide a greater understanding of dairy cow behaviour. In the context of this study, preference testing has provided a novel approach to highlighting specific problems that subordinate animals are confronted with at the feed-face; especially during periods of high competition. Some current housing and feeding designs in the UK are not efficient enough or suitable for modern dairy farming. The modern dairy cow is significantly larger than thirty years ago, when much of the existing accommodation was constructed. The problem is compounded by an increase in average herd size without farmers taking due account of the need to increase the size of the housing facilities (DEFRA, 2006). The information gained from this study can be used in conjunction with other quantitative studies recommending alterations to various aspects of the feeding environment, including space allowance (Lang et al., 2007), feed barriers (Huzzey et al., 2006) and stocking density (Kondo et al., 1989) and used to design an improved feeding situation. By designing an improved feeding system, producers should be able to maximise efficiency of production and improve cow comfort and welfare. This experimental technique could also be used to identify the different physical and environmental factors that low status cows use to make their decision. For example the behaviours observed in this study could vary by altering factors such as space allowance at the feed-face, food quality and stage of lactation. By creating a comfortable and suitable feeding environment, for all cows within a group, it should be possible to maximise feed intake and improve production and welfare.

3.5 Conclusions

Low status cows preferred to feed alone than next to a dominant animal when the same quality of food was offered. When they were asked to trade-off feed quality with feeding next to a dominant animal, the majority still chose to feed alone on low quality food. These results suggest that social status within a herd could significantly affect feeding behaviour, especially in situations of high competition and for subordinate individuals.

CHAPTER 4

Dairy cow feeding space requirements assessed in a Y-maze choice test

Abstract

A Y-maze choice test was used to investigate how subordinate dairy cows make decisions relating to the proximity to a dominant cow whilst gaining access to a high quality feed. The main aim of the experiment was to determine the feeding space allowance at which the majority of subordinate cows would choose to feed on high quality food (HQF) next to a dominant cow rather than feeding alone on low quality food (LQF). Thirty Holstein Friesian cows were used in the study. Half of the cows were trained to make an association between a black bin and high quality food and a white bin and low quality food. The other half was trained with the opposite combination. The social status of each cow was assessed and pairs were made up of a dominant and a subordinate cow. When cows had achieved a HQF preference with an 80% success rate in training, they were presented with choices using a Y-maze test apparatus in which cows were offered choices between feeding on HQF with a dominant cow and feeding on LQF alone. Four different space allowances were tested at the HQF feeder: 0.6m, 0.9m, 1.2m and 1.5m. At the two smaller space allowances, cows preferred to feed alone (choices between feeding alone or not for 0.6m and 0.9m tests were significantly different; $P<0.001$ and $P<0.05$ respectively). For the two larger space allowances cows had no significant preferences (number of choices for feeding alone or with a dominant ($P>0.05$ and $P>0.05$ respectively). Given that low-status cows are willing to sacrifice food quality in order to avoid close contact with a dominant animal, it is suggested that the feeding space allowance should, where possible, be in excess of 0.90m per cow. However, even when space allowances are large, it is clear that some subordinate cows will still prefer to avoid proximity to dominants individuals.

4.1 Introduction

Feed intake, particularly dry matter intake (DMI), is the main contributor to the volume of milk produced by dairy cows. It is therefore economically important for producers to maximise feed intake across the whole herd, which may also benefit cattle health and welfare. The most popular type of feed barrier on dairy farms in the UK is a post and rail barrier. This system consists of a series of posts along one side of a pen, with a simple strap or metal rail preventing cows from stepping over the pen boundary and into the feed. It is generally assumed that feed barriers provide all animals within the herd with equal access to the food. However, this is unlikely to be the case as dairy cows live within a hierarchical social structure and dominant animals can monopolise resources.

Cows prefer to feed at certain times of day (Grant and Albright, 2001; Cook et al., 2004; DeVries et al., 2004), sometimes referred to as peak feeding times, which generally occur around the time that cows return from milking and when fresh feed is delivered. These periods are when most cows are present at the feed-face and levels of aggression and competition are at the highest (DeVries et al., 2003b).

Given a standard feeding space allowance, subordinate cows choose to feed alone rather than next to a dominant cow (Rioja-Lang et al., 2009). Subordinate cows continued to choose to feed alone even when they were made to trade-off the feed quality to be able to do so (Rioja-Lang et al., 2009). This led us to consider how varying space allowances would affect the subordinate cows' choices, and ultimately allowing us to make more specific recommendations for housing regulations. The assumptions made when using the Y-maze choice test are that animals make choices that are in their own best interests and that understanding animals' preferences will help us to improve their welfare (Frazer and Mathews, 1997).

Prior to testing, cows were trained to make associations between colour and feed quality before being presented with a choice of high quality food (HQF) and low quality food (LQF), which were provided in feed troughs of different lengths. All

HQF presentations were accompanied by a dominant cow feeding at a neighbouring trough while all low quality options were presented without another cow.

The main aim of this work was to determine the feeding space allowance at which the majority of subordinate cows would change their choices from feeding alone to feeding next to a dominant individual, if that dominant individual was presented beside HQF. It was predicted that subordinate cows would choose to feed on LQF rather than feeding on high quality food near a dominant cow when the feeding space was low (i.e. spaces that are representative of industry practices). However, it was also predicted that this preference would reverse by increasing the feeding space allowance.

4.2 Materials and Methods

4.2.1 Animals and housing

Thirty lactating Holstein Friesian cows were used in the study, as three groups of 10. Half of the cows were multiparous (parity = 4.2 $\pm$ 1.9; mean $\pm$ SD) and half were primiparous. All cows were housed in a cubicle shed at the SAC Dairy Research Centre, Dumfries, Scotland. The cows were separated from the rest of the herd 24 hours before the experiment began and housed in a separated area of the cubicle housing within the main shed where they had free access to feed and water. After testing sessions, cows were returned to the main cubicle area where they had access to a TMR, which was formulated to provide adequate nutrients for maintenance and milk production. The cows were not fed any additional concentrates during milking. Fresh feed was delivered once a day (whilst the cows were in the testing arena) and they generally had access to it within 1 hour of their normal feeding time.

4.2.2 Test procedure and testing arena

For further details see section 3.2.2

4.2.3 Dominance Testing

For further details see section 3.2.3

4.2.4 Training procedure

For further details see section 3.2.4

4.2.5.1 The experimental procedure - choice test between feeding alone or next to a dominant.

To determine whether subordinate cows did choose to feed alone or whether they did so because the dominant cow physically blocked them from feeding at a trough, trained cows were presented with a bin of HQF at the end of each arm of the Y-maze. A dominant cow was presented alongside one of the feed bins. Each cow was tested four times over four days, and the location of the dominant cow was randomised over the trials. To determine choices the test arena was split into two zones (Figure 4.1). These zones represented the side the dominant cow was occupying (1), and the unoccupied area (2) and the amount of time that a subordinate cow spent in each zone of the arena was recorded.

4.2.5.2 Choice test between feed quality and proximity to a dominant.

In the experimental choice tests subordinate cows were presented with a feed bin containing HQF with the dominant cow present, and a feed bin containing LQF, without another cow. Four different treatments were tested, using four different sizes of feed bins: 0.6m, 0.9m, 1.2m and 1.5m. These distances ranged between the smallest, that was very likely to result in subordinates choosing to feed alone on LQF (as found by Rioja-Lang et al, 2009), to the largest space, 1.5m, which is more than double the industry standard, and was intended to allow dominant and subordinate cows to feed comfortably next to each other. Each cow was presented with a choice test once a day for four days. The arm of the Y-maze in which the dominant cow was positioned and the order of presentation of the space allowances were randomised across all cows.

4.2.6 Data collection and statistical analyses

For each choice test the number of times an individual cow chose each option was recorded. Sign Tests were used to test for a significant difference between the number of times an option was chosen ($P<0.001$). Wilcoxon Signed Ranks Tests were used to test the significance of the difference between the choices made over the different space allowances.

4.3 Results

It took 18 training sessions for 12 cows to all achieve the specified criteria of 8 correct choices out of 10 in consecutive sessions. One pair from each group of 5 pairs that did not reach the criteria was dropped from the study. The number of choices between feeding alone or not for 0.6m and 0.9m were significantly different ($P<0.001$ and $P< 0.05$; Table 4.1). For the two larger space allowances there was no significant difference between the number of choices for feeding alone or with a dominant ($P>0.05$ and $P>0.05$ respectively).

Table 4.1 Preferences for feeding alone at the four different space allowances (Sign Tests).

Space Allowance	N	Below	Equal	Above	P
0.6m	12	0	1	11	< 0.001
0.9m	12	1	3	8	< 0.05
1.2m	12	3	4	5	> 0.05
1.5m	12	5	2	5	> 0.05

Below refers to the number of cows that chose to feed with the dominant cow more often. *Equal* refers to the number of cows that chose both options an equal number of times. *Above* refers to the number of cows that chose to feed alone more often.

Table 4.2 displays Wilcoxon Sign Rank results between the choices made over each of the space allowances. The aim of this is to highlight the space allowance which the cows started to alter their preferences for feeding alone or next to a dominant.

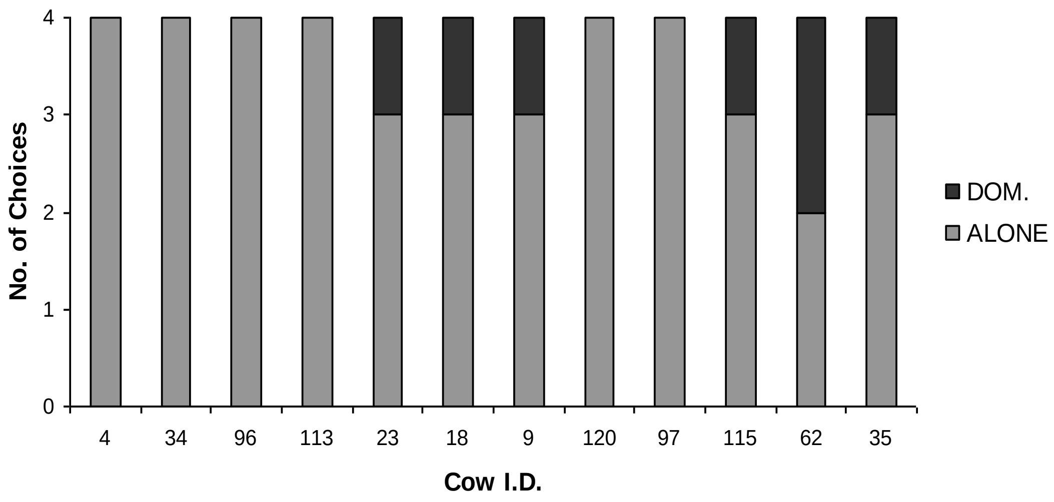
This result illustrates that there was no immediate significant difference in choices made over individual stages of the tests.

Table 4.2 Wilcoxon Sign Rank Test of choice patterns made between all Choice Tests.

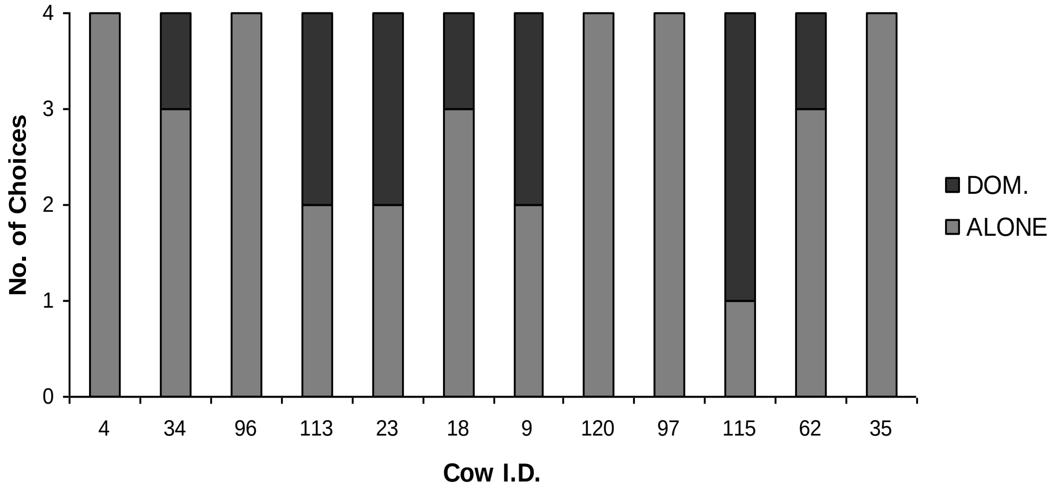
Choice Patterns Between Tests	N	Z	P
0.6m & 0.9m	12	22.0	0.205
0.9m & 1.2m	12	23.0	0.151
1.2m & 1.50m	12	8.0	0.353

For the smallest space allowance (0.6m) it appeared that most of the test cows chose to feed alone on LQF rather than next to a dominant cow (Figure 4.3 (a)).

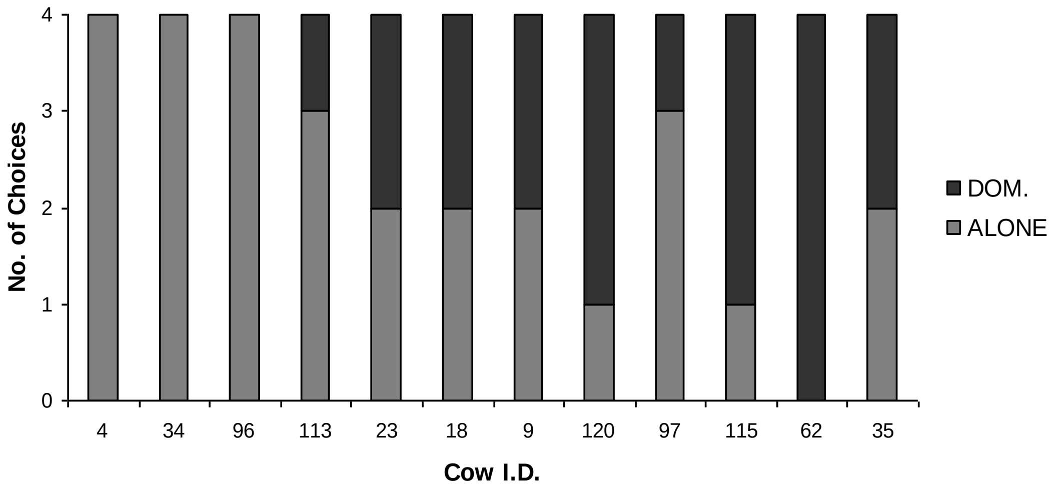
a)



b)


No. of Choices
0
1
2
3
4
4
34
96
113
23
18
9
120
97
115
62
35
Cow I.D.
DOM.
ALONE

c)


No. of Choices
0
1
2
3
4
4
34
96
113
23
18
9
120
97
115
62
35
Cow I.D.
DOM.
ALONE

d)

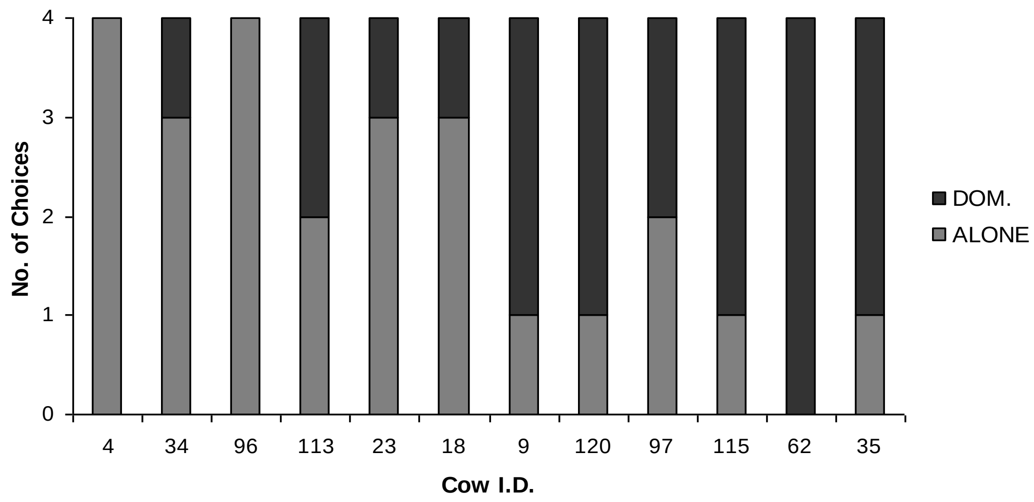


Figure 4.3 The choices of individual cows for feeding alone or feeding with the dominant cow at 4 different feeding space allowances (a) 0.6m space allowance (b) 0.9m, (c) 1.2m and (d) 1.5m.

Once the space allowance was in excess of 0.9m (Figure 4.3 (b)), subordinate cows showed no preference for eating either LQF alone or HQF next to a dominant cow ($P>0.05$).

4.3.1 Time spent in zones of arena

Over all of the different space allowances subordinate cows spent 39% of their time standing alone in the test arena and 61% was spent standing in the same side as the dominant cow. It appears, then, that even though a subordinate cow did not feed next to a dominant cow, she may in some instances have been blocked from the feed bin instead of actively choosing to feed alone.

4.4 Discussion

When space allowances at feed troughs were small (<1.0m), cows preferred to feed alone on low quality food than to feed on high quality food next to a dominant cow. Even when the feeding space was increased to 1.5m, some cows did not switch to preferring to feed from the high quality feed trough. In this case, choices became more variable and an overall switch in preference was not seen.

Perhaps a more consistent result would have been observed if the test cows were higher yielding cows, i.e. they may be more likely to want access the higher quality of feed due to increased pressure to attain greater nutrient requirements, even regardless of the social pressure they face. There is a lack of information on whether cows under greater metabolic stress resulting from high levels of milk yield, respond differently from low yielding cows to changes in space allowance. One study by Fregonesi and Leaver (2002) investigated this issue by comparing varying space allowances of two different housing systems and for high and low yielding cows. They concluded that they found no evidence that high and low yielding cows responded differently to changes in space allowance, and they suggested that their housing requirements are similar. It would be interesting to repeat this experimental design using cows of differing yielding potential.

Our data are consistent with DeVries et al.'s (2004) findings that when provided with more space at the feeder, cows increased the distance to their nearest neighbour, leading to reduced frequency of aggressive interactions and increased feeding. Stolba (1985) reported that increasing trough lengths for feeding pigs decreased the extent to which the food could be defended allowing subordinates access to feed without being in close contact with dominant. Proximity to dominants at feeding time appears to be a very important consideration for low social status animals.

If feeding space is limited, increased competition among cows at the feeder may lead to some cows modifying their feeding times to avoid aggressive interactions (Miller and Wood-Gush, 1991). If subordinate cows are forced to feed out-with preferred peak feeding times they may compromise their nutritional intake and thus be less productive. By providing more space at the feed-face, more cows could feed more effectively and efficiently. The potential for increasing access to food for all of the individuals within a herd should increase feed intake and decrease feeding rate. Reducing the level of competition at the feed-face should, therefore, be a priority for dairy producers.

In the UK, dairy cows are generally housed for around 6 months of the year over the winter period, however, systems in which cows are housed continuously throughout the year are becoming more common as cows can be fed high levels of concentrate feed more easily when they are housed (Haskell et al., 2006). At present, housing regulations contain very few specific requirements. The current UK recommendation from the Department for Environment, Food and Rural Affairs (DEFRA) is that if animals are expected to feed simultaneously, the feed-face required per cow should be dependent upon the size of the animals (DEFRA, 2006). For example, cows weighing between 500-700kg require a feed-face of at least 0.6–0.7m. If, however, feed is available 24 hours per day the feed-face allowance can be reduced by as much as 75% leaving a space allowance of 0.15-0.17m per cow (a space that is smaller than the hip width and body width of Holstein dairy cows (Enevoldsen and Kristensen, 1997)). Due to the increase in continuous housing, it is therefore essential to house cattle in the most efficient, and comfortable, way possible. It is also necessary to provide and enforce more robust housing regulations.

Preference testing has provided a novel approach to highlight specific problems that subordinate animals are confronted with at the feed-face (see also Rioja-Lang et al., 2008). There are a very limited number of studies that have used the Y-maze testing method with cattle (Grandin et al., 1994; Hosoi et al., 1995; Prescott et al., 1998; Pajor et al., 2003) and never before to investigate the effect of social dominance at the feed-face. Successful learning performances have previously been reported in cows before (e.g. Pajor et al., 2003; Arnold et al., 2007) supporting the effectiveness of this type of approach with farm animals. This experimental technique could also be used to identify different physical and environmental factors that low status cows use to make their feeding decisions, for example the introduction of head-dividers, different group compositions and different stages of lactation. The high genetic merit of modern dairy cows' capacity to produce milk largely exceeds that of the capacity to consume sufficient nutrients for milk synthesis. Therefore, in order to maximise feed intake, and subsequently milk production, it is important to provide a suitable feeding environment for all individuals within the herd.

4.5 Conclusions

Low status cows prefer to feed alone than next to a dominant animal, particularly below a space allowance of 1.2m per pair. Therefore, it is recommend that on farms, the space allowance should be sufficient enough for all cows within a herd to have, an excess of 0.9m/cow where possible; allowing them to feed simultaneously during preferred feeding times.

CHAPTER 5

Effects of an Automated Feed Recording System on Feeding Behaviour of Lactating Dairy Cows

Abstract

The feed barrier has been shown to have a major effect on feeding and social behaviour of group housed dairy cows. A barrier design that provides some sort of separation between cows has also been shown to reduce competition. Recent advances in the development of computerised recording systems have resulted in a renewed interest in collecting continuous feeding and drinking behavioural data. However, in order to allow only one animal to feed at a time the set up of this system has been designed to prevent other cows from gaining entrance into the feed bins when another cow is occupying the bin. Although this design does assist in preventing more than one animal consuming feed at a time it also prevents the animals from seeing other conspecifics within the pen. Thus, the objective of this experiment was to test the prediction that obscuring the visual field of cows during feeding will increase vigilance behaviour and, in turn, will alter normal feeding behaviour. The effect of stocking density and aggressive behaviours was also observed. Thirteen primiparous and 11 multiparous (parity = 2.4 ± 0.67; mean ± SD), mid-stage lactation Holstein cows were used and divided into 4 groups. Two pens had a headlock feed barrier and the other 2 pens had an electronic feed system (Insentec, Marknesse, Holland). The cows were moved into their groups and given a period of 7 days to stabilise. Groups were exposed to all four treatments (6, 5, 4, or 3 feeding spaces per pen) over both of the feed barrier types following a repeated Latin Square design. Between each treatment there was a baseline period of 2 days. Behaviours were recorded over 24 hours. The number of displacements at each feeding system were observed and used to estimate the social status of each individual. The level of vigilance scans observed did not differ significantly between the two feed barrier types ($P>0.05$). The results show that cows spend more time feeding when using a headlock barrier compared to an electronic Insentec feeder ($P<0.05$). There was no effect of space allowance on levels of vigilance behaviour or presence at feed-face.

5.1 Introduction

Numerous studies report that group feeding of cattle results in competition between animals, with the extent of competition increasing when feeding space is restricted (Oloffson, 1994; Huzzey et al., 2006; Lang et al., 2007). Cows differ in their competitive abilities, yet many intensive food animal production rearing systems are designed on the assumption that resources will be shared equally between all individuals (Monaghan and Wood-Gush, 1980). Cows are especially motivated to access feed in the hours immediately following delivery of fresh feed (Friend and Polan, 1974; DeVries et al., 2003a), and this is when competition for feed is highest (Huzzey et al., 2006). Moreover, the effects of limited feeding space are most detrimental for subordinate cows (DeVries and von Keyserlingk, 2006).

The design of the feed barrier (where cattle gain access to feed) has been shown to affect feeding and social behaviour of group-housed dairy cows (Endres et al., 2005; Huzzey et al., 2006). It has been suggested that feed barriers that provide some separation between cows (e.g. headlocks or feed-stalls) reduce competition by making it more difficult for cows to engage in aggressive interactions (DeVries and von Keyserlingk, 2006; Huzzey et al., 2006).

Computerised recording systems allow continuous monitoring of feeding and drinking behavioural data for loose-housed cows (Gibb et al., 1998; Chapinal et al., 2007) and are frequently used in research. However, these feeders are often designed to prevent multiple cows from using the same feeding station at the same time, but these physical barriers may also prevent visual contact between the animal that is occupying the feeding station and other cattle within the pen. Obscuring the cow's visual field may prevent scanning while feeding, an important aspect of vigilance behaviour.

Vigilance is a behaviour that increases the likelihood that an animal will detect a given stimulus at a given time (Dimond and Lazarus, 1974). For intensively housed animals where aggression at the feed-face is often present, vigilance behaviour may also impact feeding and social behaviour, and these effects may be greatest for animals having a lower social status than their conspecifics. This behaviour has also been shown to increase with the need to monitor conspecifics, for example, to avoid aggression (Trouilloud et al., 2004). Prey animals have been observed altering their vigilance levels, at the expense of feeding time, in response to predation risk (Welp et al., 2004).

In a group of a size that allows adequate opportunity for social interaction, the dominance hierarchy can be so stable that a single day's observation can determine the order. A dominance index of individual animals can help to compare the experiences and effectiveness of individuals in agonistic/competitive encounters at the feeder (Val-Laillet et al., 2008). The use of an index also provides a quick and easy individual parameter of dominance that can be used to rank the animals and estimate their susceptibility to miss out on access to important resources (Grant and Albright, 2001).

The objective of this experiment was to test the prediction that obscuring the visual field of cows during feeding will increase vigilance behaviour and, in turn, will alter feeding behaviour. The aim was also to investigate if this would be further affected by stocking density or social status. It was predicted that this visual obstruction would increase vigilance behaviour and reduce feeding times, especially for socially subordinate animals.

5.2 Materials and Methods

5.2.1 Animals, Housing and Diet

Thirteen primiparous and 11 multiparous (parity = 2.4 ± 0.67; mean ± SD) high-producing mid-lactation Holstein cows of high genetic merit were used in the study. All cows were housed in a cubicle housed barn at The University of British Columbia Dairy Education and Research Centre (Aggasiz, British Columbia, Canada) and divided into 4 groups, each consisting of 6 cows. Cows were randomly assigned to an experimental group, and all 4 groups were balanced according to parity, number of days in milk (DIM), and milk yield. Each cow produced an average of 37l/cow/day over 305d lactation. In all pens there were 12 stalls filled with 40cm of washed river sand, and rubber flooring on the central passage. All cows were cared for according to the guidelines outlined by the Canadian Council of Animal Care (Olfert et al., 1993). The cows were fed a total mixed ration consisting of 26.7% corn silage, 12.3% grass silage, 11.13% grass hay, 49.8% grain / protein supplement on a dry matter (DM) basis. Fresh feed was provided at approximately 0600h and 1600h and in the pens fitted with the headlock barrier the feed was pushed up closer to the cows four times a day. Cows were milked between 07.30h and 08.30h in the morning and between 17.30h and 18.30h in the afternoon. All animals were moved into their experimental groups and allowed to stabilise for 7 days before the study began.

5.2.2 Experimental Design

Two pens had a headlock feed barrier design and the other 2 pens had an electronic feed intake system (Insentec, Marknesse, Holland), with both types of feeding system having 6 feed bins. Each cow was fitted with an ear tag containing a unique passive transponder (High-Performance ISO HalfDuplex Electronic ID Tag, Allflex Canada, St-Hyacinthe, Quebec, Canada). As cows approached the feed, an antenna detected the cow’s transponder and lowered the barrier, allowing her access to the

TMR. When the cow finished eating and left the bin, the barrier would close until the next cow approached. For each visit to the bin, the system recorded the cow number, the bin number, the initial and final times and weight and calculated the duration and intake.

Within each barrier treatment, 4 stocking densities were tested: 6, 5, 4, or 3 individual feeding spaces per cow, corresponding to 1.00m, 0.83m, 0.67m and 0.50m headlocks per cow. Initially, 2 groups had a head lock barrier while the other 2 groups were fed using the Insentec feeders. Each group was tested at each stocking density in 4 successive 10-d treatment periods, with density applied to group using a Latin square design. Once each group had received each of the 4 stocking density treatments on their respective feed barrier design, the groups were switched to the alternate barrier type and the process was repeated. Stocking density treatments were assigned to groups in the same manner as the first half of the experiment.

5.2.3 Behavioural Recording

Behaviours were recorded continuously for 24 h/d. Feeding behaviours and aggressive interactions were recorded using Panasonic WV BP330 cameras positioned approximately 2m above the experimental pens. One camera was mounted above the feed-face of each experimental pen. The cameras were attached to a Panasonic video multiplexer (WV-FS416) and time-lapse recorder (AG-6540). Red lights (100W) were hung directly above (approximately 4m) the pens to facilitate video recording at night. Individual animals were identified using unique alphanumeric symbols made with hair dye.

5.2.4 Vigilance Scans

The number of vigilance scans were recorded continuously over a period of 24 hours. Due to cows' wide field of vision, it is difficult to determine when a cow is able to see any given object when its head is raised. However, for the purposes of this study, and as in other studies of vigilance in ungulates and other mammals (Underwood, 1982; Hunter and Skinner, 1998; Childress and Lung, 2003) the cows were considered to be vigilant when their heads were raised (Welp et al., 2004). A vigilance event was recorded each time a cow had her head fully in a feeder/feed space, and her head was raised more than 15 cm above the bottom of the feed bin for any period of time.

5.2.5 Aggressive Behaviours

The number of displacements per cow at the feed-face were observed and used to give an estimation of the social status of each individual. A displacement was noted when a cow's head (actor) came in contact with a cow that was feeding (reactor), resulting in the reactor withdrawing its head from the feed face, as described in (Huzzey et al., 2006). These behaviours were observed in the first 180 min post-feed delivery throughout the experiment, as this is when the greatest number of aggressive interactions occurring at the feed-bunk (DeVries et al., 2003b; DeVries et al., 2004). The 'index of success' was calculated for each cow using the calculation (Mendl et al., 1992).

$$\frac{\text{Number of cows that an individual is able to displace}}{\text{Number of cows that an individual is able to displace + number of cows that are able to displace the individual}} \times 100\%$$

Figure 5.1 Calculation of 'index of success' (Mendl et al., 1992).

5.2.6 Statistical Analyses

Genstat (GenStat®, 7th Ed., Lawes Agricultural Trust, VSN International Ltd., Oxford, UK) was used for all statistical analyses, with pen as the experimental unit. The number of times a cow was present at the feed-face was recorded using 10 minute scans over a 24h period of video footage. Restricted Maximum Likelihood (REML) linear mixed models were fitted to the data. Vigilance behaviour data were not normally distributed therefore they were first log transformed to produce a binomial distribution and then analysed using a REML model. Type of feed barrier, space allowance and dominance rank was entered as a fixed model, with the random model as group, day, and cow I.D.

The dominance index was constructed from the frequency of displacements recorded over a 180min period after the delivery of fresh feed (twice per day). According to their position on the index, cows were then assigned to one of two categories, either 'High' or 'Low' dominance.

5.3 Results

The results (Table 5.1) show that there was a significant difference between the types of feed barrier ($P<0.05$). The headlock feed barrier resulted in cows spending an average of 44 minutes longer at the feed-face compared to the Insentec feed bins over 24h. The effect of dominance rank also had a significant difference on presence at feed-face ($P<0.001$) (Figure 5.3). The cows from the High dominance ranking group showed a significantly higher duration of presence at the feed-face than the cows from the Low category (267.7 min. and 225.4 min. respectively). The number of feeding spaces per group did not have a significant difference on the presence at feed-face.

Figure 5.2 displays the mean duration of the presence at the feed-face over a 24h period. This is shown for the two different feed barriers and for the four space allowance treatments.

Table 5.1 Significance test of duration of time that cows are present at the feed-face (estimated over 24 hours using 10 min scans).

	W	D.F.	P
Type of Barrier	4.44	1	<0.05
No. Feeding Spaces	2.37	3	>0.05
Dominance Ranking	27.93	1	<0.001

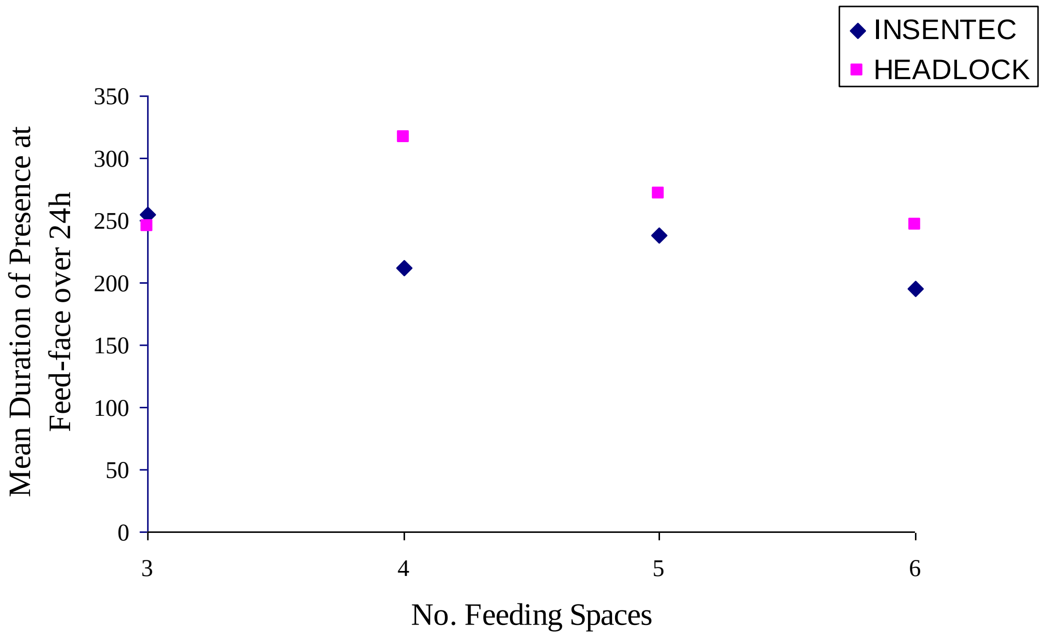


Figure 5.2 Average length of time cows are observed at the feed-face (estimated over 24 hours using 10 min scans).

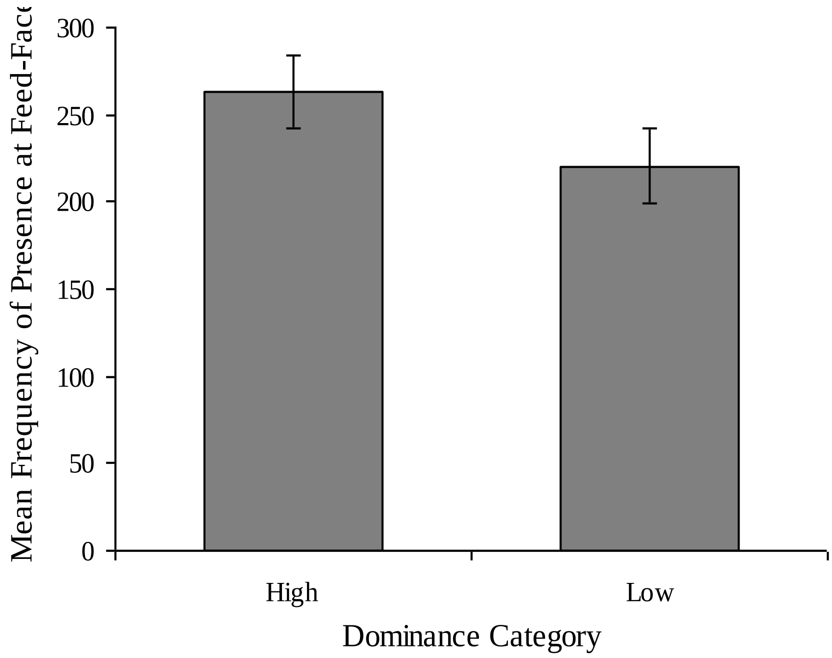


Figure 5.3 The effect of dominance status on the presence at the feed-face.

The number of times a cow performed a vigilance scan whilst feeding at the feed-face was recorded during the periods of highest intensity of feeding: 3 hours after the delivery of fresh feed and return from milking. The results show that there was no significant difference between types of feed barrier, number of feeding spaces or dominance rank (Table 5.2). The low status cows did, on average, scan slightly more times than the high status cows (102 versus 95 respectively).

Table 5.2 Significance test of duration of vigilance scans over two 3 hour periods.

	W	D.F.	P
Dominance Ranking	1.76	1	>0.05
No. Feeding Spaces	1.44	3	>0.05
Type of Barrier	0.03	1	>0.05

5.4 Discussion

The levels of vigilance scans in dairy cows did not differ significantly between the two feed barrier types; contrary to our predictions. However, there was a significant difference between the length of time that cows spent feeding between the two feed barriers, and between high and low ranking animals.

The main aim of the study was to investigate if obscuring the visual field during feeding would have an effect on the prevalence of vigilance scans, and also if this would be further affected by stocking density or social status. Specifically, cows feeding from an open feeding system (a conventional headlocking barrier where cows had an unobstructed view of the pen) and from feed bins (that likely obstructed the animals visual field) were compared. There were no significant differences of level of vigilance behaviour for either barrier type. This may indicate that the cost of high levels of vigilance is not as important as time spent feeding. There was a slight indication that subordinate animals scanned more whilst feeding than dominant cows, although this was not significant. Perhaps a more distinctive difference would have been observed if the level of feeding competition was increased even further, or if treatments had been observed over a longer period of time. The results show that cows spend more time feeding when using a headlock feeder instead of the electronic Insentec feed barrier. This result was not necessarily expected as the Insentec feed barrier provides a substantial physical barrier between the cows and the feed. While it was not possible to measure individual feed intakes as the headlock barrier feeds the cows as a group, comparing group intakes was also not possible due to an unexpected water leakage which affected the remaining feed of the headlock groups.

There were no significant effects of space allowance on presence at the feed-face. This indicates that despite the number of feeding spaces being reduced, all cows within the group were still able to gain access to feed. Perhaps observations of feeding rate or actual intake would have shown a difference. A longer term study would be useful which could also investigate the effects on milk production and group feed intakes.

When feeding inhibits an animal's ability to scan its environment and vice versa, a conflict will exist between the two behaviours (Lima and Dill, 2008). In this instance, vigilance behaviour was measured as it has been recognised to increase with the need to monitor conspecifics, for example, to avoid aggression. Unfamiliar environments or herd mates may favour higher vigilance because potential sources and locations of danger are not familiar or known. Prior to the start of the experiment the study animals had been housed in different groups within the main herd. However, due to frequent regrouping of cows for other research trials, previous social relationships between animals could not be determined. Although vigilance remains in the behavioural repertoire of dairy cows, the lack of predation over evolutionary time may have had other effects (Welp et al., 2004). It has also been suggested that one of the effects of domestication is increased genetic and phenotypic variability in behaviours that are less important in captivity than in the wild (Price, 1999). In other words, if a particular behaviour is not commercially important it will not be selected for when producing breeding strategies. Selected behaviours in farm species include such things as handleability, docility, mothering ability etc therefore leading to potential increased variability in other areas e.g vigilance.

There have been very few studies comparing different types of cattle feed barriers, and only two studies, to our knowledge, which compare an electronic feeding system with a conventional feeding system; Ferris et al (2006) and Phipps et al (1983).

However, this is the first study to investigate the effect of feed barriers on vigilance behaviours. It was initially thought from anecdotal observations that cows may spend less time feeding from the automatic feed bins as they can be noisy and obtrusive. It is very important to fully understand how electronic feeding systems affect feeding behaviour as they are very commonly used in research institutes worldwide, and therefore could have an effect on the outcome of many scientific studies.

A recent study carried out by Ferris et al (2006) compared an electronic feeding system (Calan Gate) with a conventional feeding system for dairy cows. They concluded that there was no difference in feed intake between feeding systems and that this supported the findings of a preliminary study of (Phipps et al., 1983). However, in the study by Ferris et al (2006) the design of the two systems meant that a maximum of three animals, from a group of twelve, were only able to feed at any one time from the Calan gates compared to a maximum of eight animals with the conventional system. This would have inevitably led to a competitive situation particularly at peak feeding times. In a competitive situation, certain individuals would be more likely to miss out on access to feed i.e. lower ranking cows. They also report that the Calan gate animals substituted feeding time with queuing in the feed passage, and also had an increased rate of feed intake. If cows are not able to gain access to feed at peak feeding times, they may be forced to shift their feeding times to other times of day, including late at night (Forbes, 1995). A well-designed management system should adequately accommodate optimal feeding behaviour i.e. cows prefer to eat in frequent, short bouts during specific times of day: on return from milking and after delivery of fresh feed (Grant and Albright, 1995).

All groups of cows regularly displayed vigilance behaviour, although it was not significantly different between feed barriers. Therefore, in conclusion, dairy cows can be vigilant without incurring costs of reduced feeding time, providing adequate resources are available. This may be a specific domestication adaptation to dairy housing and production, where feed intake is the primary concern to dairy cows. To conclude, the results from this study suggest that automated feeding gates do not adversely impact on vigilance levels whilst feeding. Additionally, cows were observed spending greater lengths of time feeding at the traditional headlock system than at the Insentec system. As monitoring feeding and drinking behaviour in loose housed cows is very difficult, validated electronic monitoring systems will continue to provide researchers with continuous feeding and drinking behavioural data, provided there is no (or little) competition for access to the feeding stations.

5.5 Conclusions

Frequencies of vigilance scans did not differ significantly between an electronic and conventional feed barrier. Cows spent more time present at the conventional headlock feed-barrier, and dominant cows spent more time feeding during peak feed times than subordinate cows. It is therefore concluded that neither the electronic feeding system nor stocking rate affect vigilance in dairy cattle, at least over the treatment conditions assessed in the current study.

CHAPTER 6

General Discussion

6.1 Introduction

The overall objective of this thesis was to assess the implications of various factors on the feeding behaviour of dairy cows. The three main areas of the study were; i) to assess how the amount of space available at the feed-face affected intake, aggression and production, ii) to understand how dairy cows perceive their feeding environment with specific emphasis on subordinate animals and how they are affected by feeding next to dominant individuals, and iii) to assess how feed barrier type and stocking density affects vigilance scanning and feeding behaviour. As profit margins in dairying are often small, and with increased public pressure on producers to comply with animal welfare standards, a study that investigates the welfare and housing aspects of feeding in dairy cows would assist in addressing these issues.

In the UK, dairy cows are generally housed for around 6 months of the year, over the coldest period, however systems in which cows are housed continuously throughout the year are becoming more common. Despite this, housing regulations contain very few specific requirements. The broader aim of this series of experiments was to provide practical advice and better understanding for dairy producers in creating an optimal feed area design. The aim was to do this by highlighting the importance of non-nutritional factors on feed intake and feeding behaviour. In the past, feeding behaviour has been approached from a predominantly nutritional point of view. The composition of the diet is of obvious importance, however, as we now know, there are many other factors, apart from nutrition which affect feeding and feed intake. Scientists and dairy farmers are also able to use knowledge of animal behaviour to improve cow well-being. This chapter aims to provide an overview of the results from the studies reported in the previous chapters and how they relate to the scientific literature on the feeding behaviour of dairy cows with specific emphasis on the non-nutritive factors. Finally, the areas that require further research, will be highlighted to conclude.

6.2 Space Allowances

The first approach of assessing feeding behaviour in dairy cows was to investigate how the physical attributes of the feeding area affects feeding behaviour. The first aspect of the feeding area that was considered was the effects of space allowance. Since researchers have previously suggested that a common standard measurement of 0.6m of feeding space per cow fails to allow all animals to access feed at preferred feeding times (Friend and Polan, 1974; DeVries et al., 2003; DeVries et al., 2004), I strived to investigate if providing a greater amount of feed-face space could increase the amount of feed intake and reduce aggressive behaviours and displacements. In Chapter 2 it was described how three different space allowances representing low, standard and high allowances, would affect feed intake, milk yield and aggressive behaviour. It was found that as the space allowance increased, the number of aggressive interactions and displacements both decreased. When provided with extra space at the feed-face, cows did not increase their feed intake as hypothesised, and intakes appeared to remain fairly stable over the various treatments. A likely explanation for this result is that differences in feed intake did occur between individual animals, although, these were masked by the overall group effect. Despite any restrictions imposed on cows at the feed-face, the most dominant cows will always gain access to feed. Therefore, an effect may be observed among the more subordinate cows. There was also a significant difference between milk yields of each treatment, although it was not a large difference. In fact, the yields (averaged over the three collection days) from the smallest and standard space allowances were almost identical (30.2kg ± 0.6, 0.8 respectively). The most probable reason for this is that length of treatment was not long enough; perhaps a period of approximately 21 days would show a more distinctive effect of the treatment; with a possible decrease in milk yield for certain animals at the lower space allowance. The only way to overcome these problems would be to observe long term studies to validate the full effect of space allowances at the feed-face and to also try and relate this to dominance status. Unfortunately, the data from this experiment did not allow us to construct a robust dominance index.

The role of spacing during feeding is an important subject since it has implications both for production, as related to feed intake, and for housing design (Manson and Appleby, 1990). A well-designed management system should adequately accommodate optimal feeding behaviour. However, the intensification of animal production systems has resulted in groups of animals living in close proximity to each other, often competing for limited resources (Val-Laillet et al., 2008). Also, when the economics of dairy farming are difficult, farmers will attempt to maximise profitability by putting more cows into the existing space. It is likely they recognise the overall milk yield increase in the herd, but do not consider that some cows in the herd (usually the youngest) are being compromised. It is important from economic and animal welfare perspectives to understand the potential effects of manipulating group size, density and distribution of resources on aggression in captive populations of domestic animals (Estevez et al. 2002).

The density at which we choose to stock farmed species has the potential to largely influence their behaviour. Some species, such as cattle, form large group sizes in the wild, however, other species, such as poultry and pigs, generally would form much smaller group sizes than they are housed under modern farming conditions. Large group sizes can lead to damaging behaviour, aggression and increased fear and stress levels (Rodenburg, and Koene, 2007). Problematic behaviours such as feather pecking and cannibalism in laying hens has been found to be influenced by group size and stocking density. Savory et al (1999) found the most feather damage occurred at the largest group size and at high stocking densities. Regarding cannibalism in hens, Koene (1997) found more incidences of cannibalism on commercial farms with large flock sizes, with flocks varying from 80 to 1500 birds. In pigs, the risk of damaging behaviour may also be associated with increased group size (Rodenburg, and Koene, 2007). Group size has been found to be a risk factor in vulva biting in dry sows, which has also been related to the occurrence of tail biting on the same farm (Rizvi et al., 1998).

When cattle are stocked at high densities, it becomes very difficult for animals to avoid violation of inter-individual distances; consequently there is an increase in the level of agonistic interactions. The results from our first study indicated that as the space allowance increased the feeding bouts became shorter and more frequent. The number of aggressive interactions and displacements from the feed-face also decreased as space allowance increased. Although there is little evidence to support it, it is possible that increased competition at the feed-face may have long term effects on dairy cows. In a preliminary study by Leonard et al (1998), it was suggested that cows that engaged in a high number of aggressive interactions at the feed-face had more severe claw-horn lesion scores three months after the experiment compared to those that did not engage in such encounters.

From a number of studies (Ferris et al., 2006; Lang et al., 2007) it has been suggested that reduced space allowances do not decrease feed intake. Ferris et al (2006) concluded from their study that when competition for feed space was increased, the cows modified their feeding behaviour and increased their intake rate. Dairy cows are known to be adaptable in many aspects of husbandry, not just feeding behaviour. Feed intake is rarely affected as the less competitive or subordinate animals will eventually change their feeding patterns and maintain their feed intake at non peak times or by increasing feeding rate (DeVries et al., 2006; Ferris et al., 2006; Hosseinkhani et al., 2008). Dairy cows will even show a behavioural adaptation to inadequate environments. However, this adaptability should not be exploited as it may be putting the animals under excessive or chronic stress. It is plausible to suspect that if an animal has to deviate away from its own optimum, then its welfare may be compromised. Nielsen (1999) stated that animals have a preferred daily intake, a preferred eating rate, a preferred daily feeding pattern, and they also prefer to eat together with conspecifics (allelomicry). Therefore, animals will try to defend these characteristics but they will solve this equation by changing one or more of those characteristics according to the external and internal environments. Almost no studies have observed the impact of competitive environments on feeding behaviour over a sustained period of time, and these investigations are required for the future. There has however, been several suggestions as to the potential risks faced by subordinate cows not feeding at their preferred times. Previous research has reported that increased time spent standing by cows led to significant increases in hoof health problems. It is known that in over crowded conditions, low ranking cows have to spend more time standing in the passageways (Wierenga, 1990) and that first lactation cows that stand for more time during the housing period than adult cows suffer more from sole haemorrhages (Galindo and Broom, 2000). Therefore, it is likely that the susceptibility of a cow to lameness depends on how the social and physical environment influences the duration and location of lying and standing times. DeVries and von Keyserlingk (2006) carried out a study comparing three different space allowances (0.64m, 0.92m and 0.87m with feed-stall partitions). They found that cows spent 23 minutes longer per day standing in the feeding area while not feeding (inactive standing) when they had 0.64m of feed bunk space compared with when they had 0.92m of feeding space. It is possible that this increase in sole lesions could be reduced by the provision of softer/less abrasive flooring. In the past, hard surfaces such as asphalt and solid or slatted concrete have been used in Europe and North America. However, recently, farmers seem to prefer rubber covered floors, providing access to pasture, or a separate loafing area. Equally, however, the animals could be provided with more feeding space per cow which would reduce the need to stand in the first place. The other potential serious health risk is ruminal acidosis. Nutritionists attribute subclinical acidosis and reduced performance to erratic feeding behaviour and intake by cattle (Shwartzkopf-Genwein, et al, 2003). The incidence of acidosis may also be increased due to inadequate design of the facilities and could reflect an increase in welfare problems. Research indicates that lactating dairy cows demonstrate higher degrees of feed sorting against longer forage particles and for smaller grain concentrate particles when fed a low forage diet (DeVries et al., 2007). Regardless of the cause for sorting, this behaviour can be problematic, especially for high risk cows as it reduces the buffering capacity in the rumen and increases the risk of acidosis occurring. As the susceptibility of dairy cows to acidosis appears to be highest for cows in early lactation (Penner et al., 2007), they should be the most affected by competition at the feed-face. It has also been proposed that high concentrate diets may increase stereotypic behaviours such as tongue rolling (Redbo et al., 1996; Redbo et al., 1997; Faleiro et al., 2007). In addition, the lack of roughages decreases ruminal pH, and seem to increase liver abscesses and ruminal epithelium damage although performance might not be affected (Harvey et al., 1968).

The balance between finance and welfare is difficult to set. High-concentrate rations are necessary to sustain high levels of production and return profit. However, cattle have evolved to digest forages, not concentrate.

Competition at the feed-face has also been recognised as being a particularly serious problem during specific phases of the dairy cows' life cycle. For example, Proudfoot et al (2009) have highlighted that during the transition period (a particularly vulnerable period of time due to risk of infections, metabolic diseases, and lameness) competition at the feeder can potentially further increase the risk of lameness and disease. They reported an increased number of displacements for both primiparous and multiparous animals in the competitive feeding environment which is in agreement with the results for Chapter 2 (increased competition due to reduced feeding space). Also, DeVries and von Keyserlink (2009) have investigated the effect of competition on feeding behaviour of young, growing dairy heifers. They reported 10% shorter feeding times and 9% fewer meals per day for competitively fed heifers, particularly at peak feeding times. They concluded that competition for feed for growing dairy heifers alters feeding patterns, and reduces access to feed.

Cows are highly motivated to access the feed-face upon the delivery of fresh feed and on return from milking. Being denied access to this resource could inevitably cause an element of frustration within some individuals. Allowing them to access feed at times when they show the greatest motivation to feed should allow them to meet their nutritional requirements in a manner which maximizes their feeding behaviour (DeVries, 2006). Most dairy farmers offer fresh feed once or twice per day, however DeVries et al (2005) recommend providing fresh feed on a more regular basis as an optimal husbandry practice. It is thought this should lead to reduced competition and a more even distribution of resources between individuals.

6.3 Choice Tests

Cook et al., (2004) suggested that the majority of researchers who have studied stocking density at the feed-face have failed to consider how increased competition at the feed-face affects individual cows. The methods used for the experiments described in Chapters 3 and 4 specifically aimed to address this point, as previous approaches had largely involved group studies (e.g. Friend et al., 1977; Kondo et al., 1989; Huzzey et al., 2006; Lang et al., 2007). In this instance, choice tests were used to determine how individual cows perceive their feeding environment with specific emphasis on understanding the challenges that low ranking animals face when forced to feed in the presence of socially dominant cows. The Y-maze test was used as it assumes that animals make choices that are in their own best interests. Hence, by giving animals the environments that they themselves have chosen we should be reducing suffering and consequently improving welfare (Bateson, 2004). In this instance, when offered a trade-off situation between food quality and proximity to a dominant cow, low status cows showed a marked preference for feeding alone rather than next to a dominant individual. Low status cows also traded-off food quality for feeding alone rather than next to a dominant cow. The test cows ranked avoidance of the dominant cow as being even more important than food quality, despite the obvious importance of nutritional intake. These results suggest that proximity between individuals is such an important factor that it is able to inhibit or alter feeding by low status cows. The space allowances were then more closely (described in Chapter 4) it was observed that when provided with more space at the feed bins, significantly more cows chose to feed next to a dominant cow on high quality feed than alone on low quality feed. It is assumed this is because of the opportunity to feed further away from the dominant. When provided with the two smaller space allowances (0.60m and 0.90m) most cows chose to feed alone. This study is one of the first to use this methodology to answer a question regarding dairy cow feeding preferences with specific emphasis on the experiences faced by individuals of low status. Testing animals individually, as in this study, allowed greater control over the delivery of treatments compared to testing individuals in a group situation. This methodology could be used to investigate further factors involving feeding preferences. For example, the influence of factors such as head-dividers, different group compositions and stage of lactation on behaviour could all be investigated.

6.4 Feed Barriers

It is known that the composition and intake of a dairy cow's diet is of obvious importance. However, the way the feed is presented when the cow is housed will also affect the amount the cow is able to eat in one day. Therefore, for the final phase of the study, the actual apparatus involved with feeding was investigated. This experiment described the effects of two different feed barrier designs on feeding behaviour (Chapter 5).

A wide variety of feed barrier design exists in dairy farms throughout the UK, such as the post and rail, tombstone and diagonal types. Typically, the design of these barriers has been based on the physical size of the animals, however with most farm constructions being 20-30 years old, they no longer fit the larger sized Holstein cows. However, little is known about how variations in the barrier design affect the level of aggression and competition shown at the feed-face.

Studies by Endres et al., (2005) and Huzzey et al., (2006) both compared a post and rail feeder (similar to a strap feeder) and a headlock barrier. In both studies the headlock barrier reduced the incidence of displacements. However, displacements were still observed at the headlock barrier indicating that the neck division does not provide full protection. A recent study carried out by Ferris et al., (2006) compared an electronic feeding system (Calan Gate) with a conventional feeding system (Calan Gates with their surrounding fittings removed). They concluded that there was no difference in feed intake between feeding systems and that this supported the findings of a preliminary study by Phipps et al., (1983). Unfortunately, agonistic behaviours were not formally recorded in this study, however, casual observations noted that incidences of pushing and head-butting were observed to be more common with the Calan Gate than the conventional feeding system. This is in contradiction to the other feed barrier studies where some sort of physical divide reduces aggression (Endres, 2005).

In Chapter 5, the study investigating the effect of barrier type on vigilance scanning and feeding behaviour was described. Specifically, cows feeding from an open feeding system (head lockers where cows had an unobstructed view of the pen) and from feed bins (an automated system that likely obstructed the animals' visual field) were compared. It was predicted that this visual obstruction would increase vigilance behaviour and reduce feeding times, especially for socially subordinate animals. Firstly it was observed that there was a significant difference in feeding times between the two types of feed barrier, with cows spending on average 44 minutes longer feeding from the automated feeding system than the open feeding system. The cows from the high dominance ranking group showed a significantly higher frequency of presence at the feed-face than the cows from the low dominance category (267.7 min. and 225.4 min. respectively). The number of feeding spaces per group did not have a significant effect on the number of animals present at the feed-face. The final result showed that there was no significant difference between the number of times a cow performed a vigilance scan whilst feeding at the feed-face with type of feed barrier, number of feeding spaces or dominance rank. The low status cows did, on average, scan slightly more times than the high status although this was not significant. To conclude, these results indicate that neither feeder design nor stocking rate affect vigilance in dairy cows, at least over the treatment conditions assessed in the current study.

It is difficult to be prescriptive when describing dimensions for any type of feed barrier, as there will always be variation between herds, systems and management practices. However, we can recommend with some confidence that barriers which provide some sort of physical separations should limit competition and the frequency of displacements – as was reported by Baxter (1986) in pigs and; Endres et al (2005) in dairy cows. It has also been suggested that barrier designs which allow a greater forward reach should minimise injuries to cattle and simultaneously allow ready access to a large volume of feed. Exerting large forces against the feed barrier whilst trying to reach the food is likely to increase injuries to cattle, particularly if they slip or are displaced in the process and suffer an impact injury or torn ligament (Petchey et al., 1991).

The need to monitor and assess animal welfare standards on commercial farms is becoming an increasingly important issue as quality assurance schemes are created and expanded. In the UK, most dairy farmers are subject to oblige with some form of animal welfare standards, whether it is through the Department of Fisheries and Rural Affairs (DEFRA), a supermarket chain or the National Dairy Farm Assured Scheme (NDFAS). This is largely driven by consumer demand for farmers on how to attain high standards of animal welfare for inclusion in codes of practice and farmer guidelines (Bowell et. al., 2003). Ideally, some of the results and recommendations from this research would be used in support for more stringent requirements for suitable housing designs for dairy cattle instead of the vague recommendations discussed in Chapter 1. The situation for improving farm-animal welfare is difficult but this should not dissuade scientists and animal carers from attempting to implement change that may improve animal welfare.

The design of the feeding facility is known to have a great effect on feeding competition in most farm species. For cattle, which often displace one another when feeding by swinging and butting with the head, modifications that restrict head and neck movements may be particularly effective in reducing competition and improving access to feed (Endres et al., 2005). If feed-barriers were designed to take account of the social and feeding behaviour of the cows, feed-intake and welfare could be optimised. These studies aimed to provide sound scientific backing for the best possible design.

6.5 Future Research

Although these group and individual experiments have provided a greater insight into the effect of space and barrier type on feeding behaviour and aggression, longer term studies would understandably provide a more accurate picture of the consequences of feeding in a competitive environment. Further studies should be designed to determine the long term effects of competition on measures such as dry matter intake (DMI), milk production, stress, claw health, fertility and disease incidence.

There are several other key factors of the feeding environment and physiology of the modern lactating dairy cow which could be investigated to a greater extent. As has already been mentioned, when aspects of the feeding environment are altered, feed intake has shown to be fairly consistent within cows (mostly due to subordinate individuals altering their daily time budget). However, perhaps in order to understand the true extent of these adaptations it would be necessary to collect consistent evidence from the same subjects over several lactations.

One possibility is that when competition at the feed-face is high, some cows may be forced to stand in the passage and wait to gain access to feed. It is possible that this increased standing time could contribute to an increased risk to hoof health (Greenough and Vermunt, 1991). In a study investigating the effect of space allowance on feeding behaviour, DeVries and von Keyserlingk (2006) reported that cows spent 23 mins longer per day standing in the feeding area while not feeding when they had 0.64m of feeding space compared to 0.92m of space. Lameness is one of the most significant health and welfare issues for dairy cows (Logue and Offer, 2001; Amory et al., 2006) and also has a significant economic cost (Green et al., 2002). Prolonged standing on concrete is a recognised and important predisposing factor to lameness. Cows exhibiting longer standing times, especially on hard surfaces, are thought to be at higher risk of developing hoof and leg injuries (Greenough and Vermunt, 1991). A study that observed the time spent standing and related it to levels of lameness in individuals would test this hypothesis.

Another interesting and particularly important area for future research is the management and housing of young and freshly calved cows. It is widely known that transition cows (the period of time between a cow being in a non-lactating state to a lactating state) undergo major metabolic and hormonal changes in response to increased nutrient demands of the growing foetus, parturition and the onset of lactation (Penner et al., 2007). Between the end of a lactation and calving, these "dry" cows are often managed in a separate group from the main herd. It has been suggested that these cows often face increased competition within their new group (Grant and Albright, 1995), which may limit their access to feed, particularly for heifers as they have never been in the main herd before. This could be due to the fact that heifers often appear to attain low social status within groups of mature cows. It would be interesting to investigate the full effect of the increased competition on these animals and how management practices could be optimised to minimise stress.

Another exciting avenue for feeding behaviour research is to observe changes in short-term feeding behaviour of dairy cows that occur with the onset of health disorders (Huzzey et al., 2007; Gonzalez et al., 2008). These health problems can be anything from ketosis, or acute locomotory disorders to chronic lameness. The incidence of general health disorders has increased, possibly because they are associated with increased milk yield and production stress (Fleischer et al., 2001). Therefore, an early, reliable and efficient method of detection can allow farmers to treat the condition earlier resulting in significant economic benefits with reduced veterinary costs, and a decrease in early culling. Simultaneously, it is beneficial to fully understand how electronic feeding systems themselves affect feeding behaviour as they are routinely used in research institutes worldwide, and therefore could have an effect on the outcome of many scientific studies. The study, as described in Chapter 5, did not find a significant difference between the levels of vigilance scanning occurring between feeding systems, however, feeding behaviour was different between dominant and subordinate individuals. The cows from the high dominance ranking group showed a significantly higher frequency of presence at the feed-face than the cows from the low category (267.7 min. and 225.4 min. respectively).

6.6 Conclusions

The overall aim of this series of experiments was to further understand how non-nutritional factors influence feeding behaviour and feed intake in dairy cows, and this has largely been achieved. The work provided a novel approach as to how space allowance affects feeding behaviour, specifically for subordinate cows through the use of choice tests. This work has also provided additional information as to how a poor feeding environment can have a serious impact on the feeding behaviour of dairy cows.

Previously, the design of feeders and feed-barriers for dairy cattle has been largely based on the physical size of the cow and the need to maximise the number of animals in any given feeding space, rather than considering of the cow's preferred feeding behaviour and the effect of social interactions. Poor design may lead to lower food intake and higher levels of aggression, especially in subordinate animals, with consequent detrimental effects on animal welfare, fertility and production. From this research, it has been possible to make practical recommendations as to how the feeding environment can be managed in such a way that it reduces competition and aggression whilst feeding. Specifically, in Chapter 4, it is recommended that over-stocking should be avoided, and an excess of 0.9m/cow should be preferred where possible.

Dairy farmers can use knowledge of animal behaviour to improve cow comfort and production. In order to improve cow comfort and feeding activities, the feeding environment must be well designed and able to accommodate cows' preferred feeding behaviours. For this reason, Chapters 3 and 4 assessed individual cow preferences. In addition to what has already been investigated in these studies using this choice test method, there are many other factors that could also be assessed in this way. All of these social and physical factors, and the complex way in which they interact, must be investigated and optimised to promote maximum production, intake and behavioural standards.

In the dairy industry, there is considerable evidence that selecting for production traits alone is associated with a reduction in health and fertility (Pryce et al., 2001; Veerkamp et al., 2003). Animal husbandry has also failed to keep pace with improved genetics for yield. For example, many housing systems which were constructed decades ago no longer function effectively for the modern, larger Hostein Fresian dairy cows. It is generally accepted that farm animals have certain behavioural needs, and one of these is to be able to express normal patterns of behaviour. The Farm Animal Welfare Council (FAWC) base their philosophy around the Five Freedoms, which identify the elements that determine the ideal welfare state as perceived by the animals (Webster, 2005). Animal caretakers and society as a whole have a moral obligation to maintain cattle in a high state of welfare.

It is also important to consider farming on a global scale, not just within the UK. Intensive livestock production is booming in countries with large emerging economies. With the world facing a human population expected to reach nearly nine billion by the year 2040, the global demand for livestock products is expected to double in the first half of this century. Livestock are already hugely important globally, occupying 70% of agricultural land, and 30% of the ice-free land surface of the planet (FAO, 2007). Efficiency of management systems will also be crucial due to the inevitable consequences of climate change. It is suggested that dairy farming is the largest agricultural source of the greenhouse gases methane (CH_4) and nitrous oxide (N_2O) in Europe (Weiske et al., 2006). It is important to establish an acceptable balance between the conflict of production efficiency and welfare standards. As the numbers of livestock worldwide are due to increase, it is of even greater importance that they are raised and housed in a sustainable and welfare friendly manner. Both intensive and extensive production requires attention and intervention so that the livestock sector can have fewer negative and more positive impacts on national and global public goods (FAO, 2007). In order to optimise husbandry we must provide dairy cows with a suitable standard of housing and care which allows them to cope adequately with their environments and to perform a natural range of behaviours.

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